Digitized by the Internet Archive
in 2013

http://archive.org/details/generaltechnical4655nort

CLEMSON UNIVERSITY LIBRARY
MAR 29 1979
SCI., TECH. & AGR. DIV.
GOVT. DOCUMENTS
DEPOSITORY ITEM
MAR 28 1979
CLEMSON
LIBRARY

# Preparing Directories to Local Outdoor Recreation Facilities

by Roger E. McCay, David A. Gansner, and Jane R. Riddle

**Forest Service General Technical Report NE-46 1978**
Forest Service, U.S. Department of Agriculture
Northeastern Forest Experiment Station
370 Reed Road, Broomall, Pa. 19008

# Authors

**Roger E. McCay** is a research forester with the Forest Service's Northeastern Forest Experiment Station, Parsons, W. Va.

**David A. Gansner** is a research forester and project leader with the Northeastern Forest Experiment Station, Boomall, Pa.

**Jane Riddle** is an information specialist with the Northeastern Forest Experiment Station, Boomall, Pa.

**Manuscript received for publication 31 January 1978**

BOUND BY THE NATIONAL LIBRARY BINDERY CO. OF GA. SB 49

*Development of a good guide to local outdoor recreation facilities can be accomplished in five basic steps. Knowing your users and what information they need are key ingredients to success. The procedure outlined here was used successfully in northeastern Pennsylvania in 1976.*

The "Great Outdoors" can seem like a jungle when you're looking for recreational opportunities but don't know where to turn. Although more and more people are looking for fun and relaxation out of doors, good guides or directories to local facilities are hard to come by.

We recently asked a number of resource managers, land use planners, and researchers to list critical needs in outdoor recreation. Topping their list was the need for reliable and complete directories to facilities. Directories are useful not only as guides to available services but also as data bases for subsequent studies of outdoor recreation.

How do you inventory and prepare a directory to facilities? We faced that question during a recent project in which recreation directories were prepared for 12 counties in northeastern Pennsylvania (Northeastern Forest Experiment Station 1976). The guides were produced in cooperation with two regional planning agencies—Economic Development Council of Northeastern Pennsylvania and the Northern Tier Regional Planning and Development Commission—at a cost of about $2,500 per county. Feedback from tourist bureaus, chambers of commerce, recreation associations, newspapers, and recreationists indicates the venture is a huge success. In this paper, we review the procedure used in producing the guides.

Given the resources to do the job, preparation of a useful directory require five basic steps:

- Choose the activities to be include
- Determine the type of information needed for each activity.
- Collect the information.
- Package the information into a use product.
- Distribute the product to the user.

But remember, directories are soon outdated, so provisions must be made f keeping the information current.

# Contents


1 Choosing Activities 4

2 Deciding What to Collect 6

3 Collecting the Information 8

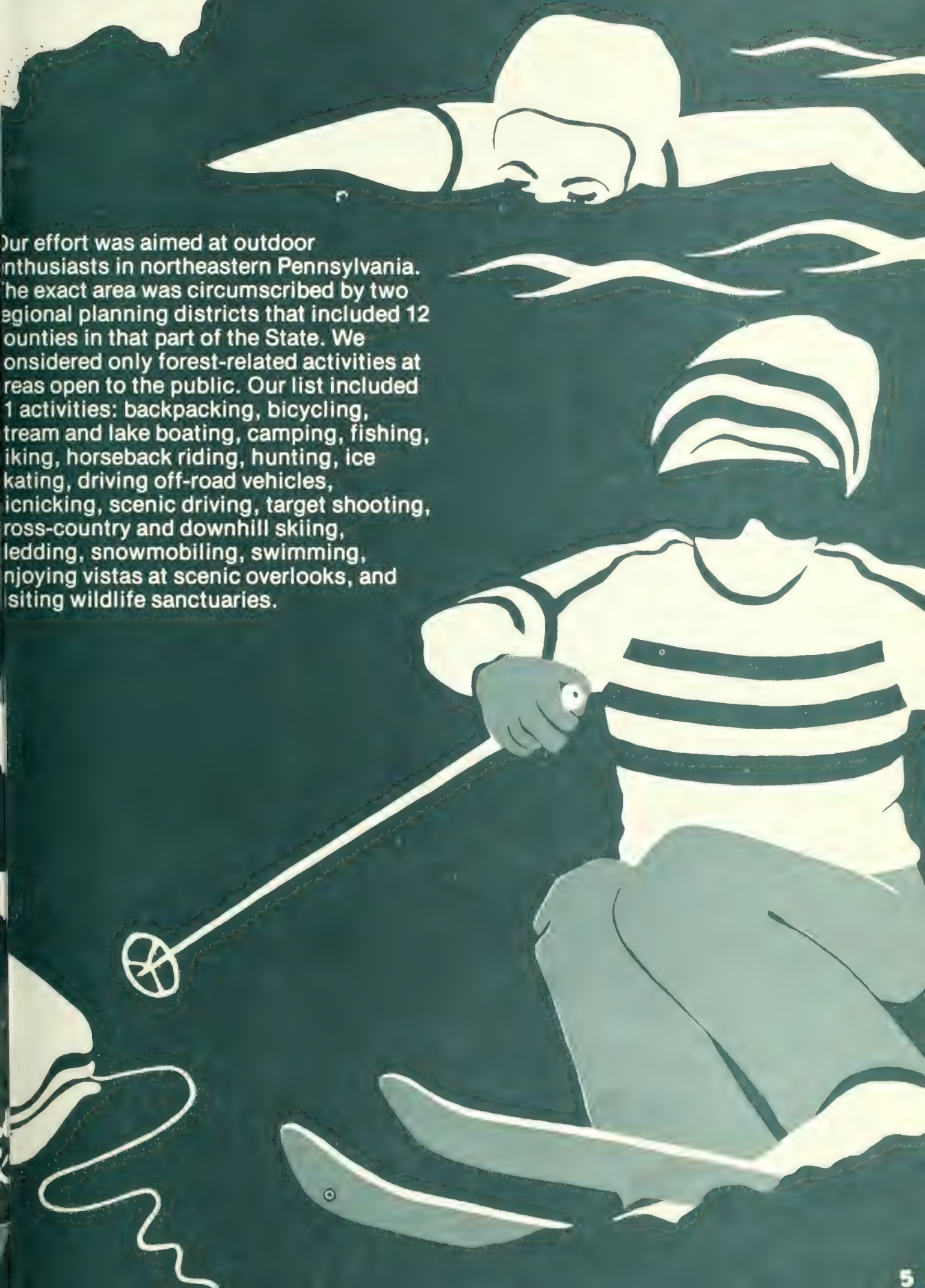
4 Packaging the Product 12

5 Distributing the Product 15

Literature Cited 16

# 1 Choosing Activities

Who? That is the question to ask in choosing activities to include in the directory. Determine your audience—what group are you trying to reach?



)ur effort was aimed at outdoor
nthusiasts in northeastern Pennsylvania.
'he exact area was circumscribed by two
egional planning districts that included 12
ounties in that part of the State. We
onsidered only forest-related activities at
reas open to the public. Our list included
1 activities: backpacking, bicycling,
tream and lake boating, camping, fishing,
iking, horseback riding, hunting, ice
kating, driving off-road vehicles,
icnicking, scenic driving, target shooting,
ross-country and downhill skiing,
ledding, snowmobiling, swimming,
njoying vistas at scenic overlooks, and
siting wildlife sanctuaries.

# 2 Deciding What to Collect

Having settled on a list of recreational activities, we set out to determine the kind of information that people would need to participate in these activities. We talked with a variety of users, examined other directories, recalled personal experiences, and came up with the following items, from which a checklist for each activity was developed. (Page 7). Included were:

- **Name**
- **Ownership:** Is it public or private? If private, users must ask permission. Indicates who to contact for information.
- **Address and telephone number:** Where to write or call for reservations or information.
- **Entrance or user fee:** Is there a charge and how much?
- **Restrictions:** Helps avoid surprises, such as "no pets allowed."
- **Facilities:** Conveniences such as electric and sewer hookups, shelters along trails, first aid station.
- **Concessions or supplies:** Items that can be bought or rented at the area—groceries, boats, camping equipment
- **Area (land and water):** Amount of area available for recreation. A water skier would not be interested in a 2-acre lake.
- **Points of interest:** Educational features that are unique to an area—historical sites, unusual rock formations, vegetation.
- **Maps and guides:** Availability of more specific information—brochures for self-guided nature trail, lake contour maps.
- **Access points and parking locations:** Safe and convenient places to start and end activities—parking areas, boat launching sites, trail heads.
- **Season of use:** Time of year that the facility is usable—campground opening and closing dates, months of low streamflow for river boating.
- **Drinking water:** Should water be brought along or can what's there be treated?
- **Length of trails:** How long an outing will it be?
- **Degree of difficulty:** Expertise or stamina required—American White Water Association ratings for rivers, tour ratings for cross-country ski trails.
- **Fish and wildlife:** Species commonly found in the area.
- **Special information:** Important items not listed above, for example, weekend square dances, river gauging stations and fishing tournaments.

| activity | name | ownership | address and telephone number | entrance or user fee | restrictions | facilities | concessions or supplies | area (land and water) | points of interest | maps and guides | access points and parking locations | season of use | drinking water | length of trails | degree of difficulty | fish and wildlife | special information |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| backpacking | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ |
| bicycling | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ |
| boating, lake | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | ✓ |
| boating, stream | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | ✓ |
| camping | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | | | | ✓ |
| driving off-road vehicles | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | | ✓ |
| enjoying vistas at scenic overlooks | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | | | | | | ✓ |
| fishing | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | | | ✓ | ✓ |
| hiking | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ |
| horseback riding | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ |
| hunting | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | | | ✓ | ✓ |
| ice skating | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | | ✓ |
| picnicking | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | | | | ✓ |
| scenic driving | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | | | ✓ | | | ✓ |
| skiing, cross-country | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ |
| skiing, downhill | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | ✓ | | ✓ |
| sledding | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | ✓ | | ✓ |
| snowmobiling | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | | ✓ |
| swimming | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | ✓ | | | | | ✓ |
| target shooting | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | ✓ | | | | | ✓ |
| visiting wildlife sanctuaries | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | ✓ | ✓ |

# 3 Collecting the Information

We used two kinds of inventory forms in collecting information for the directory. On one, we compiled information about each recreation area (page 9). On the other, we gathered data about each activity available at that area (pages 10 and 11). The "information to include" checklist was used in structuring these forms.

Most of the information on what's available can be collected from tourist bureaus, government agencies, recreation associations and clubs, chambers of commerce, recreation equipment stores, and local enthusiasts. Having exhausted these sources, go to the field to locate recreation areas that you missed, to check your data, and to fill in gaps on the inventory forms. The best sources of this information are owners and managers.

The people who do the field work should be conscientious and personable, and have an interest in outdoor recreation. We used local college interns for our inventory.

McCay, Roger E., David A. Gansner, and Jane R. Riddle. 1978. **Preparing Directories to Local Outdoor Recreation Facilities.** Northeast. For. Exp. Stn., Broomall, Pa.
20p., illus. (U. S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-46)

Development of a good guide to local outdoor recreation facilities can be accomplished in five basic steps. Knowing your users and what information they need are key ingredients to success. The procedure outlined here was used successfully in northeastern Pennsylvania in 1976.

907.2 : 904

**Keywords:** Recreation guide, mapping

McCay, Roger E., David A. Gansner, and Jane R. Riddle. 1978. **Preparing Directories to Local Outdoor Recreation Facilities.** Northeast. For. Exp. Stn., Broomall, Pa.
20p., illus. (U. S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-46)

Development of a good guide to local outdoor recreation facilities can be accomplished in five basic steps. Knowing your users and what information they need are key ingredients to success. The procedure outlined here was used successfully in northeastern Pennsylvania in 1976.

907.2 : 904

**Keywords:** Recreation guide, mapping

McCay, Roger E., David A. Gansner, and Jane R. Riddle. 1978. **Preparing Directories to Local Outdoor Recreation Facilities.** Northeast. For. Exp. Stn., Broomall, Pa.
20p., illus. (U. S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-46)

Development of a good guide to local outdoor recreation facilities can be accomplished in five basic steps. Knowing your users and what information they need are key ingredients to success. The procedure outlined here was used successfully in northeastern Pennsylvania in 1976.

907.2 : 904

**Keywords:** Recreation guide, mapping

# Area Inventory

*Lackawanna State Park*
name

*RD 1 Dalton, Pa. 18102* — *717-945-3239*
address — phone number

*Pa. Dept. of Environmental Resources*
ownership or managing agency

*1300 acres* — *220 acres*
and area — lake area

*none*
entrance fee

sample

vailable activities:

- ___ backpacking
- √ bicycling
- √ boating, lake
- ___ boating, stream
- √ camping
- ___ driving off-road vehicles
- √ enjoying vistas at scenic overlooks
- √ fishing
- √ hiking
- ___ horseback riding
- ___ hunting
- √ ice skating
- √ picnicking
- ___ scenic driving
- √ skiing, cross-country
- ___ skiing, downhill
- √ sledding
- ___ snowmobiling
- √ swimming
- ___ target shooting
- √ visiting wildlife sanctuaries

*ood concession at swimming pool, boat rental*
oncession or supplies

*Pa. State Park Regulations*
estrictions

*ummer outdoor educational classes*
pecial information

# Activity Inventory–Camping

*Lackawanna State Park*
name

*camping*
activity

*$3.00/night*
user fee

facilities

*30* tent sites

*70* trailer sites

*none* cabins

*none* laundry

*none* electric hookups

*none* sewer hookups

*yes* flush toilets

*yes* showers

*yes* dumping station

*first aid, fireplaces, playgrounds*
other

points of interest

*April to October*
season of use

*yes*
drinking water

sample

# Activity Inventory–Bicycling

*Lackawanna State Park*

ame

*icycling*

ctivity

*one*

ser fee

*ard surface roads*

cilities

oints of interest

*eneral park map at park office*

aps and guides

*everal throughout park*

ccess points and parking locations

*ocated at campground and picnic areas*

inking water

*miles*

ngth of trail

asy √ moderate strenuous

egree of difficulty

*ass 3*

ass of bikeway*

*class 1 — a completely separated right-of-way for the exclusive use of bicycles.
class 2 — a restricted right-of-way for the exclusive or semi-exclusive use of bicycles. (bike lane)
class 3 — a shared right-of-way so designated by signs placed on vertical posts or stencilled on the pavement. (bike route)

Sample

# 4 Packaging the Product

Now that you've identified your audience, know their needs, and have the information in hand, what do you do with it? Put yourself in the user's shoes. The most helpful directories are complete, accurate, and easy to use. The first two requirements can be met only by the tedious process of checking and rechecking your information in every phase of the project. In the end, it's worth the effort, since a directory full of errors won't be used.

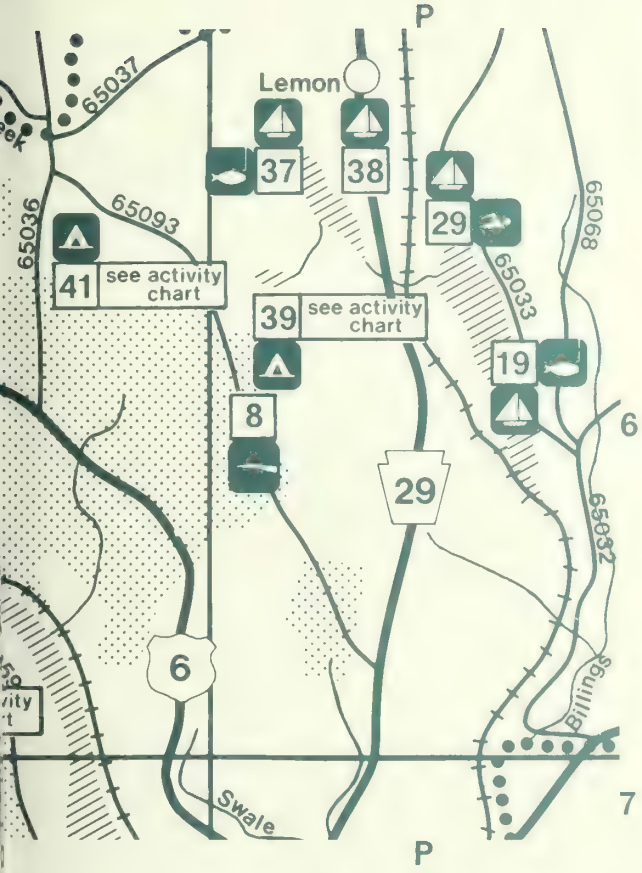
We had a lot of information which we needed to present in a way that would make it most accessible. We decided to use both maps and guidebooks.

The maps, one for each county, were printed on one side of a large sheet of paper, with activity charts on the back. They showed the name, location, and phone number of each recreation area and indicated the activities available at that area. To highlight recreation opportunities and avoid clutter, we included on the maps only those features (streams, lakes, roads, etc.) that we thought would be important to users.

The guidebooks were tailored to each county. They included a chapter on each activity—with cross-references to other activities at each recreation area—and provided details about facilities (page **14**).

**Wyoming County**
**Pennsylvania**

| name of facility | phone nu |
|---|---|
| Bowman's Creek | |
| Brickyard | |
| Camp Lackawanna | 717-833-344 |
| Camp Onawanda | 717-836-340 |
| Camp Spear | 717-945-950 |
| Ciprich's Camp | 717-869-109 |




- interstate traffic route
- U.S. traffic route
- Pennsylvania traffic route
- multi-lane divided highway
- undivided highway
- secondary roads
- railroads
- unincorporated village
- water bodies
- rivers
- streams
- trout fishing streams
- farm game projects
- fish commission lands
- state, county parks
- state forest lands
- state game lands

1 0 1 2
scale miles

| ordinates | backpacking | bicycling | boating, lake | boating, stream | camping | driving off-road vehicles | enjoying vistas at scenic overlooks | fishing | hiking | horseback riding | hunting | ice skating | picnicking | scenic driving | skiing, cross-country | skiing, downhill | sledding | snowmobiling | swimming | target shooting | visiting wildlife sanctuaries | total number of activities |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ● | | | | ● | | | | | | | | | | | | | | | 2 |
| | | | | | | | | | | | | ● | | | | | | ● | | | | 2 |
| | | | ● | ● | | ● | ● | ● | | | | ● | | | | | | | | | | 6 |
| | | | ● | ● | | | ● | | | | | ● | | | | | | ● | | | | 5 |
| | | ● | | ● | | | ● | ● | | | | | | | | | | ● | | | | 5 |
| | | | ● | ● | | | ● | ● | | | | ● | | | | | | ● | | | | 6 |

## Skiing, Cross-Country

### 3 Broad Horizons Resort
(717) 482-3491

Charles Fyfe
RD 1
Muncy Valley, Pa.

200 acres land, 3 acres water

**facility identification number**: 3
**map coordinates**: J-9
**restrictions**: must be camper to use facilities
**concessions**: cross-country ski rentals
**access points and parking**: trail head near campground
**drinking water**: in campground
**length of trails**: 2 miles
**degree of difficulty**: moderate

Other activities include lake boating, camping, fishing, hiking, hunting, ice skating, picnicking, downhill skiing, sledding, snowmobiling, swimming, and viewing scenery.

---

### 33 Ricketts Glen State Park

Pennsylvania Department of Environmental Resources
RD 2
Benton, Pa. 17814

13,100 acres land, 254 acres lake, 10 miles stream

**facility identification number:** 33
**map coordinates**: L-9, M-9
**restrictions**: see Pennsylvania State Park regulations
**maps and guides**: general map showing trails, available at park office
**access points and parking**: many areas—see map
**drinking water**: in picnic and camping areas
**length of trails**: 3 miles
**degree of difficulty**: from beginner to expert

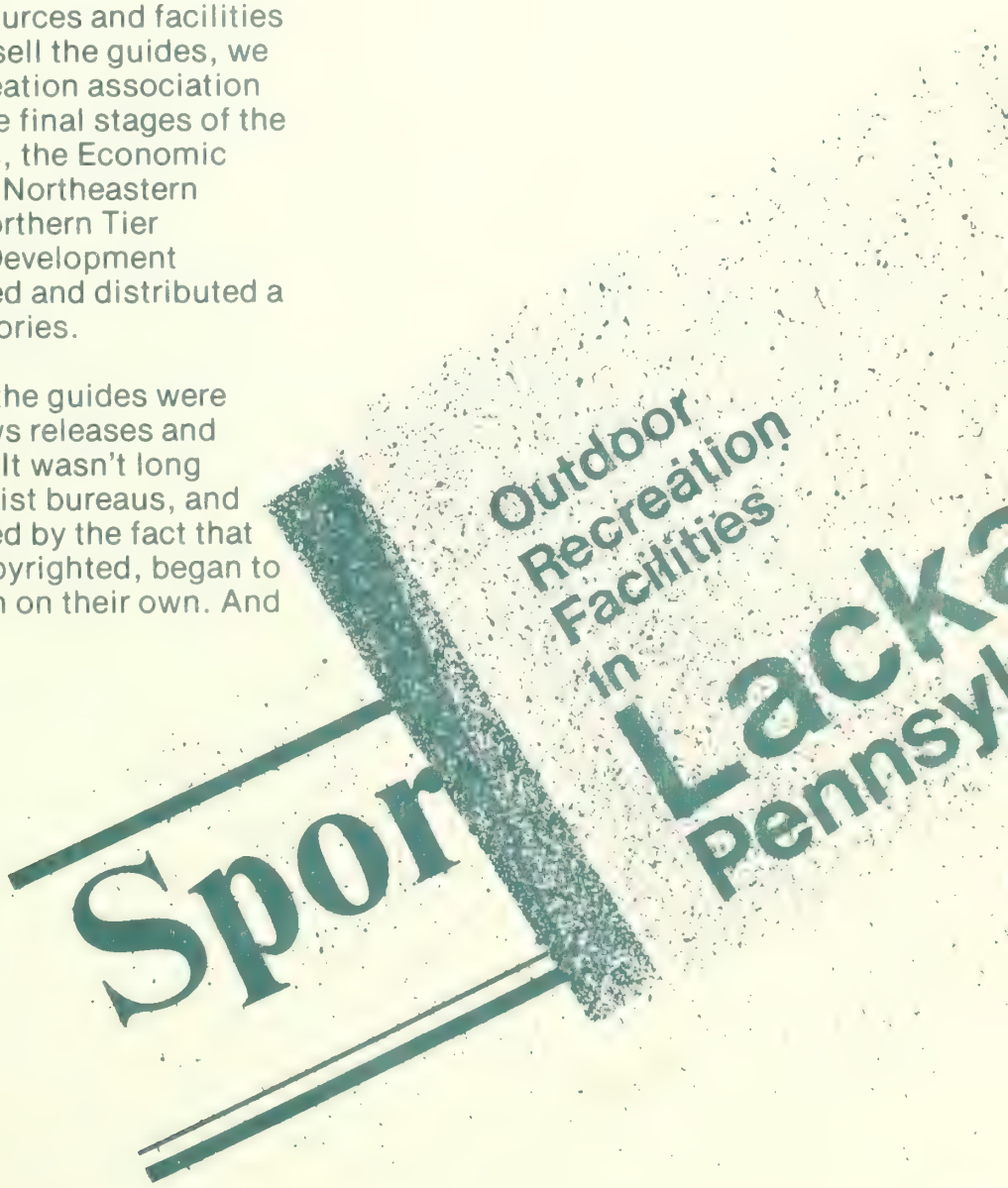
Other activities include bicycling, lake boating, camping, fishing, hiking, horseback riding, hunting, ice skating, picnicking, sledding, snowmobiling, swimming, and viewing scenery.

# 5 Distributing the Product

ur aim here is to get the directories to as any people as possible, and at the lowest st both to you and to them. Outdoor creation guides are very popular items d will break your printing budget if you ve them away. You'll find that people are lling to pay a reasonable price for them.

nce we lacked the resources and facilities print, distribute, and sell the guides, we orked with a local recreation association set up a system for the final stages of the oject. Our cooperators, the Economic evelopment Council of Northeastern ennsylvania and the Northern Tier egional Planning and Development ommission, also printed and distributed a nited number of directories.

let people know that the guides were ailable, we issued news releases and ld press conferences. It wasn't long fore newspapers, tourist bureaus, and her groups, encouraged by the fact that e directories aren't copyrighted, began to int and distribute them on their own. And at's where we are.



# Literature Cited

Northeastern Forest Experiment Station.
1976. **Outdoor Recreation Facilities in Northeastern Pennsylvania.** U. S. Dep. Agric. Northeast. For. Exp. Stn. Broomall, Pa. Misc. Publ.

For more information on this and other Forest Service research, write to:

Information Services
U. S. Forest Service
370 Reed Road
Broomall, Pa. 19008
Phone (215) 596-1628

adquarters of the Northeastern Forest
periment Station are in Broomall, Pa.
ld laboratories and research units are
intained at:

Beltsville, Maryland.
Berea, Kentucky, in cooperation with Berea College.
Burlington, Vermont, in cooperation with the University of Vermont.
Delaware, Ohio.
Durham, New Hampshire, in cooperation with the University of New Hampshire.
Hamden, Connecticut, in cooperation with Yale University.
Kingston, Pennsylvania.
Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
Orono, Maine, in cooperation with the University of Maine, Orono.
Parsons, West Virginia.
Princeton, West Virginia.
Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
University Park, Pennsylvania.
Warren, Pennsylvania.

GOVT. DOCUMENTS
DEPOSITORY ITEM
FEB
CLEMSON
LIBRARY

by Russell S. Walters and Alex L. Shigo

CLEMSON UNIVERSITY LIBRARY
FEB 14 1979
SCI., TECH. & AGR. DIV.

# TAPHOLES IN SUGAR MAPLES: WHAT HAPPENS IN THE TREE

FOREST SERVICE GENERAL TECHNICAL REPORT NE-47
1978
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
370 REED ROAD, BROOMALL, PA. 19008

## The Authors

RUSSELL S. WALTERS is a silviculturist for Sugar Maple Sap Production and Sugarbush Management Research at the George D. Aiken Sugar Maple Laboratory, Northeastern Forest Experiment Station, Burlington, Vermont.

ALEX L. SHIGO, principal scientist, is in charge of the U.S. Forest Service's Pioneering Project for research on discoloration and decay in living trees, headquartered at the Northeastern Forest Experiment Station, Forestry Sciences Laboratory, Durham, New Hampshire.

MANUSCRIPT RECEIVED FOR PUBLICATION 1 JUNE 1978

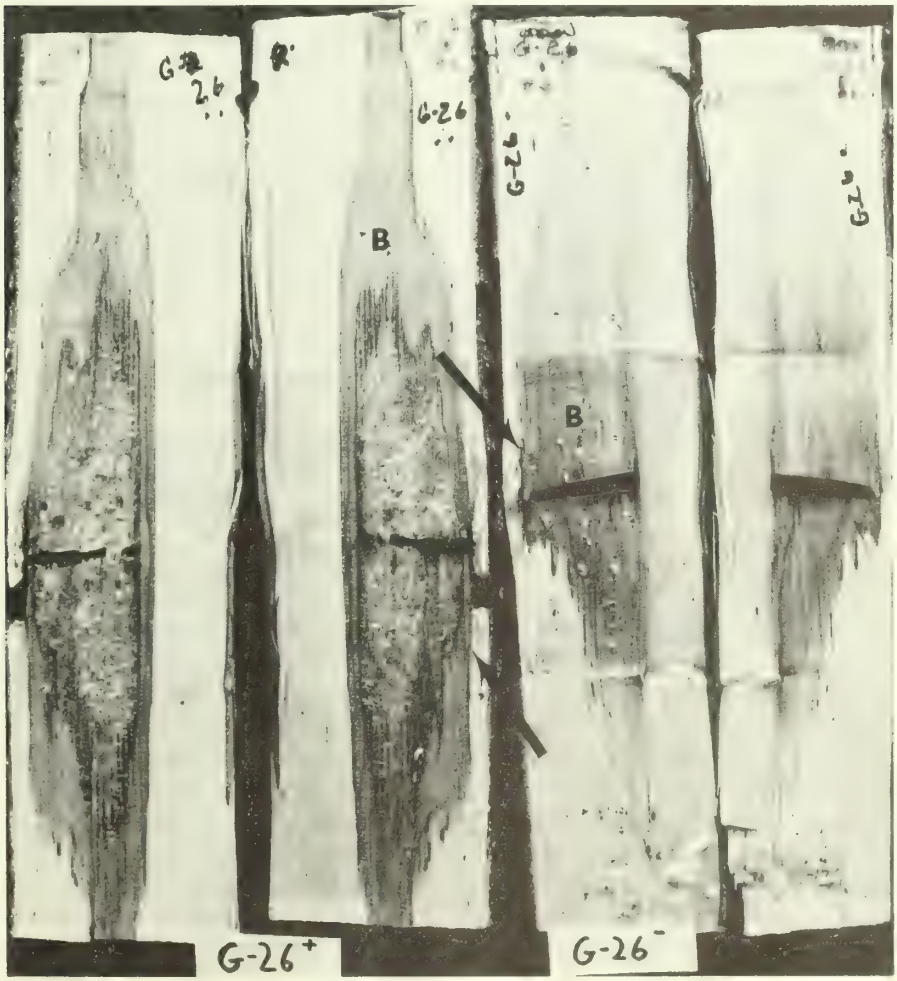
## Abstract

Maple syrup production starts by drilling a taphole in the tree. This process injures the wood, which may become discolored or decayed as a result. If trees are to be tapped, every effort must be made to minimize injury while obtaining the desired amount of sap. Information about tapholes is given here for the benefit of the producer. Some important points discussed are: how trees compartmentalize discolored and decayed wood associated with tapholes, how some tapping procedures lead to cambial dieback around the hole, the problem of overtapping related to increased use of mechanical tappers, and new information on the use of paraformaldehyde pills, which can lead to more decay in trees.

## INTRODUCTION

TO OBTAIN SAP from sugar maples for syrup production, tapholes must first be drilled in the trees. Essentially, a taphole is a wound. The vessels in the wood are severed by drilling, and the sap flows out. The resulting wound injures the wood and exposes it to microorganisms, but most sugar maple trees are tough, and they can react effectively so that some wounding does not cause internal problems. However, tapholes are frequently the source of internal problems that lead to extreme decay—even death—of trees. We need to learn how to drill tapholes without causing serious internal injury. If we can do this, trees can be tapped for many years and remain healthy. This paper gives information about tapholes that will help the operator to minimize injury to the trees, and maximize production of sap (Fig. 1).

**Figure 1.—Decayed and discolored wood associated with paraformaldehyde-treated tapholes on the left, and only discolored wood associated with a nontreated taphole from the same tree on the right. The decayed wood is surrounded by discolored wood (B). The arrows indicate the barrier zone between tissues formed before and after wounding. Unless other wounds are inflicted, the discolored and decayed wood will remain on the inside of the arrows. The decayed wood in this sample is typical of the type associated with the fungus *Coriolus versicolor*. This decay-causing fungus was the one most frequently isolated from the pill-treated tapholes.**



## WHAT HAPPENS WHEN A TAPHOLE IS MADE?

### Why maple sap flows

Maple sap will flow from a taphole in dormant sugar maples when the internal pressure of the tree is greater than the atmospheric pressure (Jones and other 1903, Marvin 1958). This occurs when certain daily changes in air temperature cause internal pressure changes—usually in the early spring, and sometimes in the fall. Cold temperatures induce a negative pressure within a tree, and moisture is absorbed through the roots. Warm temperatures induce a positive internal pressure, which forces sap from the tapholes. The volume of sap is not related to the temperature rise on the day of the flow, but rather to the length of the preceding cooling period (Marvin 1958).

Sauter (1974) suggests that sap flow is in part due to gas ($CO_2$) expansion, contraction, and solubility in response to temperature. As a result of respiration, living xylem cells generate $CO_2$, which accumulates in a gas-filled fibrous tissue surrounding the vessels and quickly dissolves in the water of the fiber walls. Larger amounts are dissolved at lower temperatures. Higher temperatures warm the tree, which drives $CO_2$ out of solution. Warming also causes the gas to expand, which compresses the vessels and creates positive internal pressure and sap flow from severed vessels (taphole). When cooled, the $CO_2$ contracts and redissolves, which creates negative pressure (relaxation of the vessels), and sap is reabsorbed.

### A tree reacts to wounds

When a taphole is drilled, the tree reacts. The living cells in the injured wood begin to change their internal processes. Substances used normally for the maintenance of the tree are shunted to materials that have protective functions (Shortle and others 1971, Tattar and Rich 1973).

As a result of a tree's chemical protective response to wounding, the wood surrounding the wound begins to discolor. In discolored wood the contents of living cells are altered. There is little or no loss of strength. The discolored wood indicates chemical changes. These include the oxidation and polymerization of phenols (Shortle and others 1971, Tatter and Rich 1973). The discoloration process intensifies as microorganisms infect the wound.

After wounding, vessel plugs begin to form (Rier and Shigo 1972) which cause the flow of sap to decrease and finally stop. The plugs are not tyloses but an aggregation of granular or gumlike amber globules that form from materials secreted from neighboring living cells (Rier and Shigo 1972, Sharon 1973). Many factors affect the rate and intensity of plugging, which differ from tree to tree. Studies with other species suggest that the processes may be under genetic control.

Soon after a wound is inflicted, it is infected by the many ever-present microorganisms. Bacteria, nondecay fungi, and decay-causing fungi all have an equal opportunity to infect fresh wounds. But the protective chemicals produced by the tree often inhibit infection by some microorganisms, especially the decay-causing fungi. Some species of bacteria and nondecay fungi digest or alter the protective chemicals. These organisms are the first to interact with the tree. They are the pioneers. Once they infect, they inhibit other organisms from growing into the wound. When decay-causing microorganisms do infect, they grow through the discolored tissues that were first inhabited by the pioneers. Decayed wood is wood in which the cell walls have been digested by the invading organisms. There is a great loss of strength. However, decayed wood does not develop from all wounds.

### Compartmentalization

When a tree is wounded, the injured and infected tissues are never replaced, repaired, or restored to their previous healthy state. In this sense, tree wounds do not heal. Instead, trees wall off, confine, or compartmentalize the injured and infected tissues. A tree is a highly compartmented plant. Each growth ring is divided into many compartments. The tangential walls of the compartments are made up of the last cells that formed in each growth ring. (The term "wall"is used here is a diagrammatic sense in the model system, not as an anatomical feature.) The radial side walls are formed by the rays. After injury, the vessel plugs form and these complete the top and bottom, or horizontal, walls to the compartments (Fig. 1). The injury also triggers protective mechanisms in the cambium, and the new cells that form after wounding are altered. This newly-formed protec-

tive tissue acts as a barrier zone that separates the wood that forms after the injury from the wood present at the time of wounding. This barrier zone is very effective in excluding the invading microorganisms from the new wood tissues. Details on compartmentalization have been published (Shigo and Hillis 1973, Shigo 1976, Shigo and Marx 1977).

The compartmenting process may be genetically controlled. Information from other tree species strongly suggests that some individuals within a species are more effective compartmentalizers than others. When several clones of hybrid poplar (*Populus deltoides* X *P. trichocarpa*) were wounded with drill holes, compartmentation ranged from excellent, where the discoloration columns were only as wide as the original wounds, to poor, where large columns of discolored wood formed. There were gradations between these extremes, but individuals of each clone reacted similarly (Garrett and others 1976, Shigo and others 1977). If this is true for sugar maple, it will be possible to select trees that are good compartmentalizers for use in maple syrup production. Such trees would withstand repeated taphole drilling, and because they would have small central columns of discolored wood, they would also be high sap producers. Small compartments of discolored or decayed wood mean more living wood is available for productive tapholes. Most sugar maples are strong compartmentalizers, but even they can develop decay problems from overtapping.

## USE OF PARAFORMALDEHYDE IN TAPHOLES

### The studies

Paraformaldehyde has been used in tapholes to increase and prolong the yield of sap. Shigo and Laing (1970) suggested that paraformaldehyde caused considerable internal injury, and the long-term effects were questioned. Two studies (Walters and Shigo 1978) were done subsequently to determine these effects. One study, started in 1970, used sugar maple trees in six different areas in Vermont. The second study, started in 1973, used sugar maple trees in Vermont, New York, Michigan, Maine, and Pennsylvania. The experimental design was similar in both studies: two tapholes were drilled in each tree. One taphole was treated with a 250-mg paraformaldehyde pill, the other was an untreated control. After treatment, the trees were dissected after selected intervals ranging from 2 months to 5 years. The vertical length of discolored and decayed wood associated with each taphole was recorded (Fig. 1), and the microorgamisms associated with the discolored and decayed wood from selected tapholes were determined.

### The results

Statistical analysis indicated that there was more decay (higher incidence and greater total length of column) associated with pill-treated than with the controls (Fig. 2). This was evident 20 months after treatment. It was true for trees in Vermont and the other states. The fungus *Coriolus* (*Polyporus*) versicolor (L. ex Fr.) Quél was the decay-causing fungus most frequently isolated from the pill-treated tapholes.

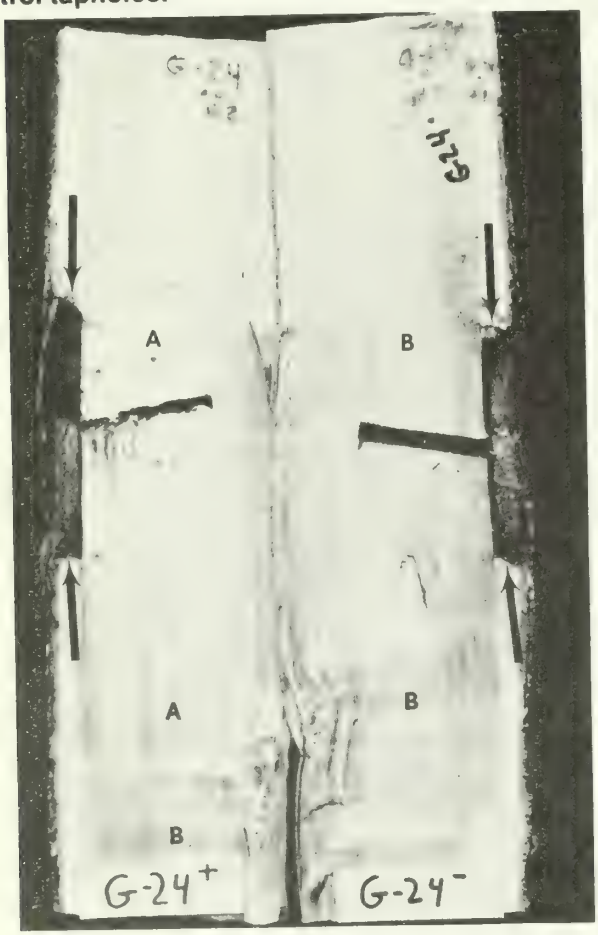
Paraformaldehyde apparently alters the tree's vascular and ray systems that play an important role in vessel plugging. When vessel plugging is delayed, the formation of the top and bottom walls of the compartments is retarded, which facilitates invasion by wood-decaying fungi. Paraformaldehyde may interfere with the usual groups of wound-infecting pioneer microorganisms. Because paraformaldehyde kills xylem cells so quickly, the normal chemicals that are antagonistic to wood-decaying fungi may not form. Thus when paraformaldehyde is used, the normal defense response, and the normal successional patterns of microorganisms, appear to be altered. In effect, the paraformaldehyde makes the hole inside the tree larger by swiftly killing many extra wood cells adjacent to the taphole.

### To use or not to use the pill

In general, we do not recommend the use of paraformaldehyde pills in sugar maple tapholes. Their use can seriously harm the tree, but whether to use them is a mangement decision. The short-range benefits of greater sap yield must be weighed against the long-range damage to the trees, and an eventual great decrease in sap yields.

On the other hand, the pill can be used when selected trees are designated to be cut within a few

Figure 2.—The arrows indicate the large dieback areas associated with the two tapholes in this tree. Although both wounds had equal dieback areas, the paraformaldehyde wound had a large pocket of advanced decay (A) surrounded by discolored wood (B). Only discolored wood (B) was associated with the control tapholes.



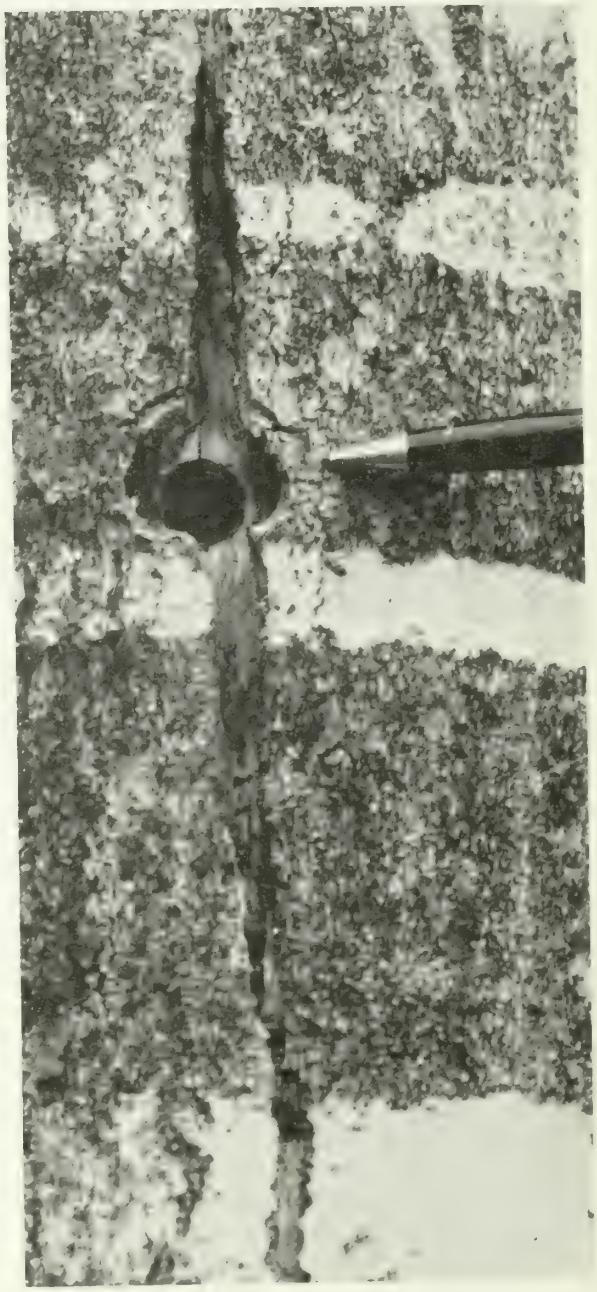

years. A maple syrup producer could then use the pill to increase the sap yield from those trees before they are cut.

## TO TAP A MAPLE TREE

### Drilling tapholes

Tapholes should be drilled as close to the beginning of the spring sap-flow season as possible. This is difficult to judge, because early warm weather does not always begin every year on the same date, nor at the same time in all parts of the maple region. If tapped too late, early sap flows may be missed; if tapped too early, the taphole may dry out before the season ends, or the trees may be frozen and seriously damaged by splitting the bark while driving in the spout (Walters 1978) (Fig. 3).

Figure 3.—A seriously damaged taphole. The bark split above and below the taphole. The dead cambium can be seen through the taphole and the split in the bark.



Tapholes are drilled in the lower portion of the tree trunk either by hand with a carpenter's brace, or by portable power (gasoline or electric) equipment. For sap collection with buckets, the hole should be about 2 or 3 feet aboveground or snow level. For sap collection with a plastic pipeline, the taphole may be placed higher, or lower, to match the pipeline configuration. Tapholes should be drilled at a slight upward pitch of about 10 degrees to facilitate sap drainage. If the holes are pitched downward, ice crystals may form in the hole which loosen the spout.

Only very sharp drills should be used to bore tapholes. A sharp drill will cut a clean-edged hole through the bark, reducing the probability of cambial dieback. A sharp drill also cleanly slices the vessels intersected by the taphole, which facilitates sap flow (Fig. 4). A dull drill makes a ragged hole; the vessels are crushed and torn. Ragged tapholes might also impede sap flow as well as make infection by microorganisms easier (Fig. 5).

**Figure 4.—This taphole was drilled with a sharp bit. Notice that the fibers at the upper and lower edges of the taphole are cleanly severed. Compare this with Figure 5.**

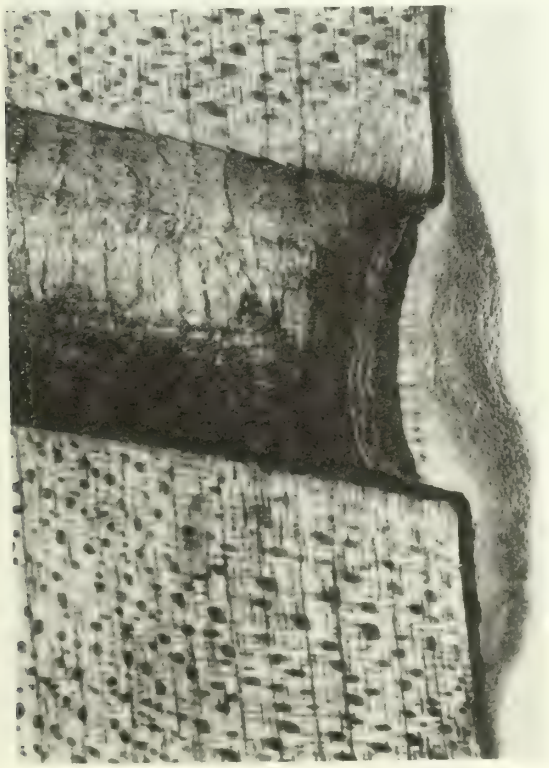


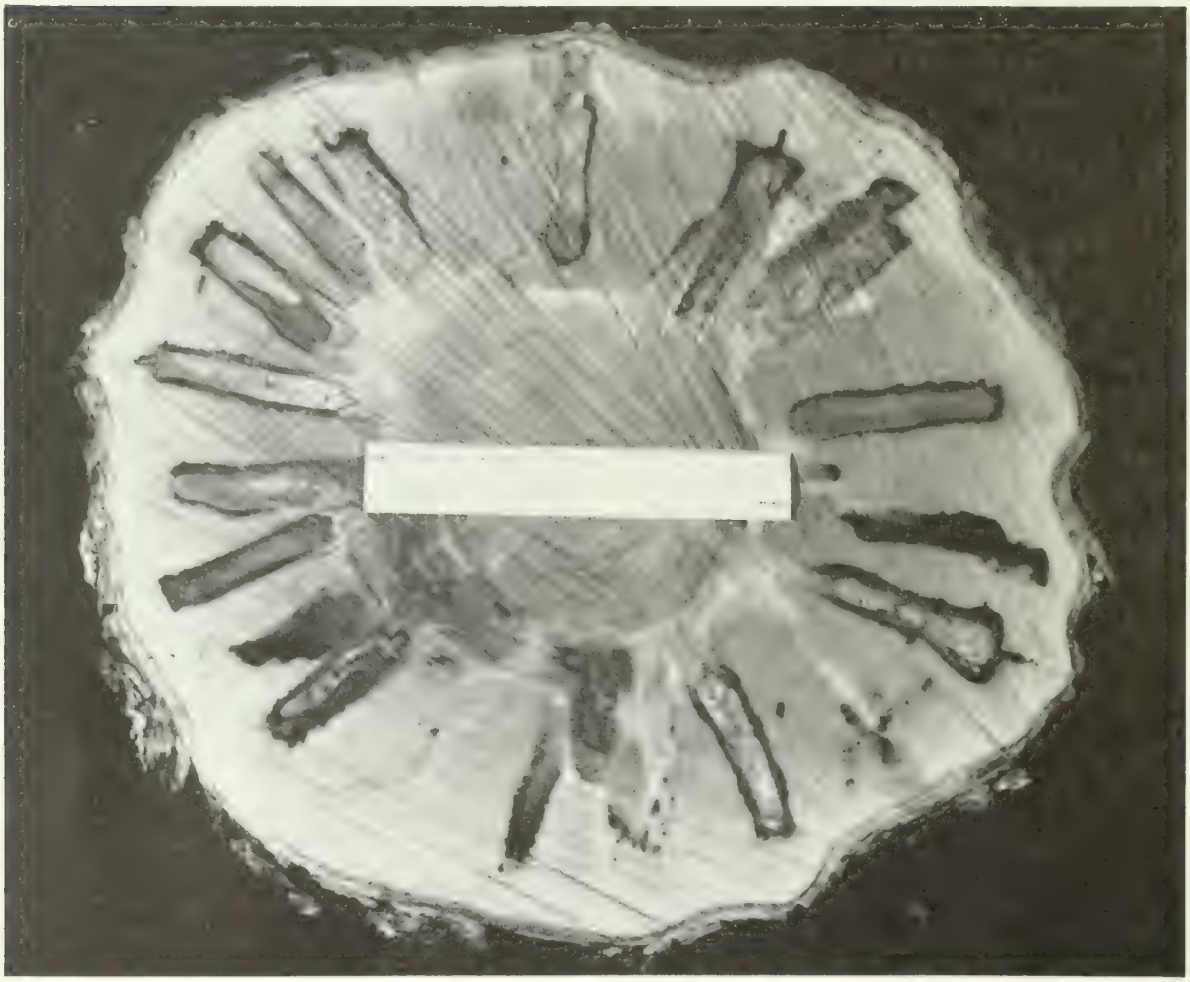
**Figure 5.—This taphole was drilled with a dull bit. The arrow indicates where the vessels were crushed and torn, leaving a tangle of fibrous materials.**

## Taphole size

In the past, drills of many difference sizes were used to make tapholes. Today, the industry uses a standard 7/16-inch-diameter drill, and spouts are designed for this size hole.

Taphole depth is not so standardized, however, and it should not be. A commonly recommended depth is 3 inches (Willits 1958). This is thought to be the optimum depth for maximizing quantity and sweetness of sap. Deeper tapholes will not yield much additional sap, and sap from deeper in the tree may have a lower sugar content (Gibbs 1969). A maximum depth of 2-1/2 inches is even better. But even 2-1/2 to 3 inches is too deep for many trees that have been heavily tapped or damaged in other ways (Fig. 6). New tapholes should not be so deep as to break into compartmented, discolored, or decayed wood. If dark wood shavings come out of the hole, it is too deep. Experience in tapping will help establish the best

Figure 6.—This sugar maple was tapped heavily, and wood decay has developed adjacent to many of the tapholes. Although the decayed wood is compartmented, the decayed zones in one area of the tree can greatly weaken the stem. These trees are likely to fall during storms, or when heavily laden with snow.



depth. When in doubt, drill a shallower, rather than a deeper, hole.

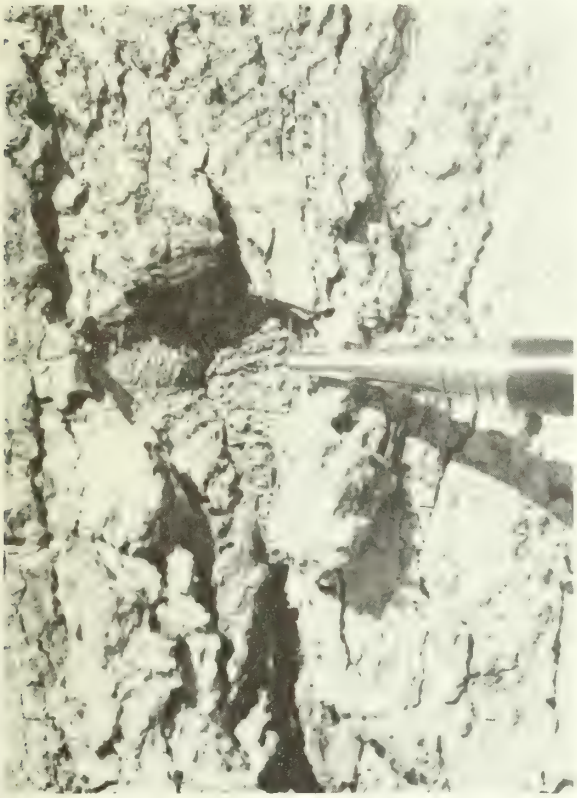
The exact width of sound wood in a tree can now be determined by using an electric meter called a Shigometer®.[1] Details of how to use this meter have been published (Shigo and Shigo 1974).

[1] The Shigometer[R] is a registered trademark for a pulsed-current meter manufactured by Northeast Electronics Corporation at Concord, New Hampshire. The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute endorsement or approval by the U. S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

## Tapping pattern

Trees may be tapped every year for many years, if the tapping is done correctly (Fig. 7). A safe tapping pattern is to drill holes no closer than 6 inches (measured around the circumference of the tree) to an old taphole until after it has closed. After new tree growth has closed over a taphole, it is safe to drill closer than 6 inches. New and old tapholes should be in a staggered pattern up and down the tree; they should not be on the same horizontal or vertical plane (Fig. 8).

**Figure 7.—When callus growth quickly closes over a taphole, the internal damage to the tree is minimized. The tree remains healthy and vigorous, and can be tapped each year for many years.**



A sugar maple tree less than 10 inches in diameter or 31 inches in circumference at the tapping zone should not be tapped. The number of taps per tree may normally be determined as follows, based on tree diameter (Willits 1958). For convenience, we have added tree sizes by circumference:

| *Tree diameter in inches* | *Tree circumference in inches* | *Number of tapholes* |
|---|---|---|
| less than 10 | less than 31 | 0 |
| 10 to 14 | 31 to 44 | 1 |
| 15 to 19 | 45 to 60 | 2 |
| 20 or more | 61 or more | 3 |

If trees are not healthy and vigorous, or old tapholes did not close rapidly, or a tree is damaged, the number of tapholes should be reduced.

## Overtapping

Overtapping seems to be more of a problem today than in former years (Figs. 9, 6). This may be due to the use of mechanical tapping equipment, because it is easy to make many holes in a short time. Overtapping does not necessarily remove too much sap, but rather, cause more injury. Too many holes means there will be too little undisturbed area for new tapholes, especially if there is cambial dieback around the tapholes. When tapholes are too close together, the resulting discolored columns coalesce inside the tree. If decay begins and quickly spreads through the discolored wood, the tree will be dangerously weakened. Even without decay, the large areas of discolored wood leave very little sap-producing wood for future tapholes.

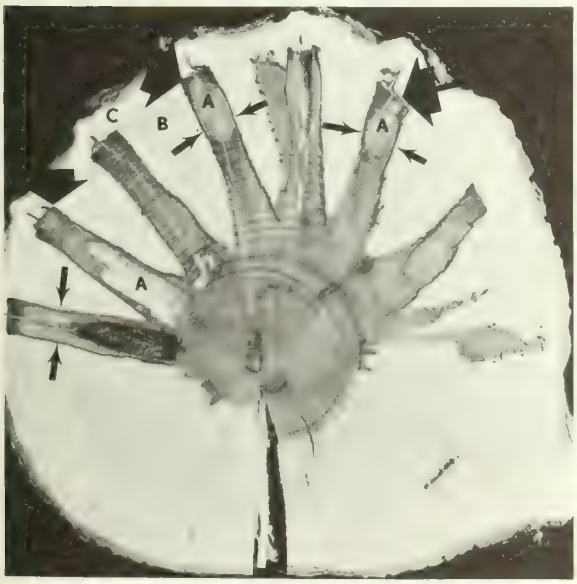



**Figure 8.—This sugar maple was tapped excessively on one side. Decayed wood (A) was associated with some of the tapholes. Slightly discolored wood (B) formed between the tapholes. The arrows indicate the radial compartmentalization of the tapholes. The large arrows indicate the barrier zone. The clear wood (C) continued to develop after the trees were tapped. The boundaries of tapholes are often bright green in sugar maple.**

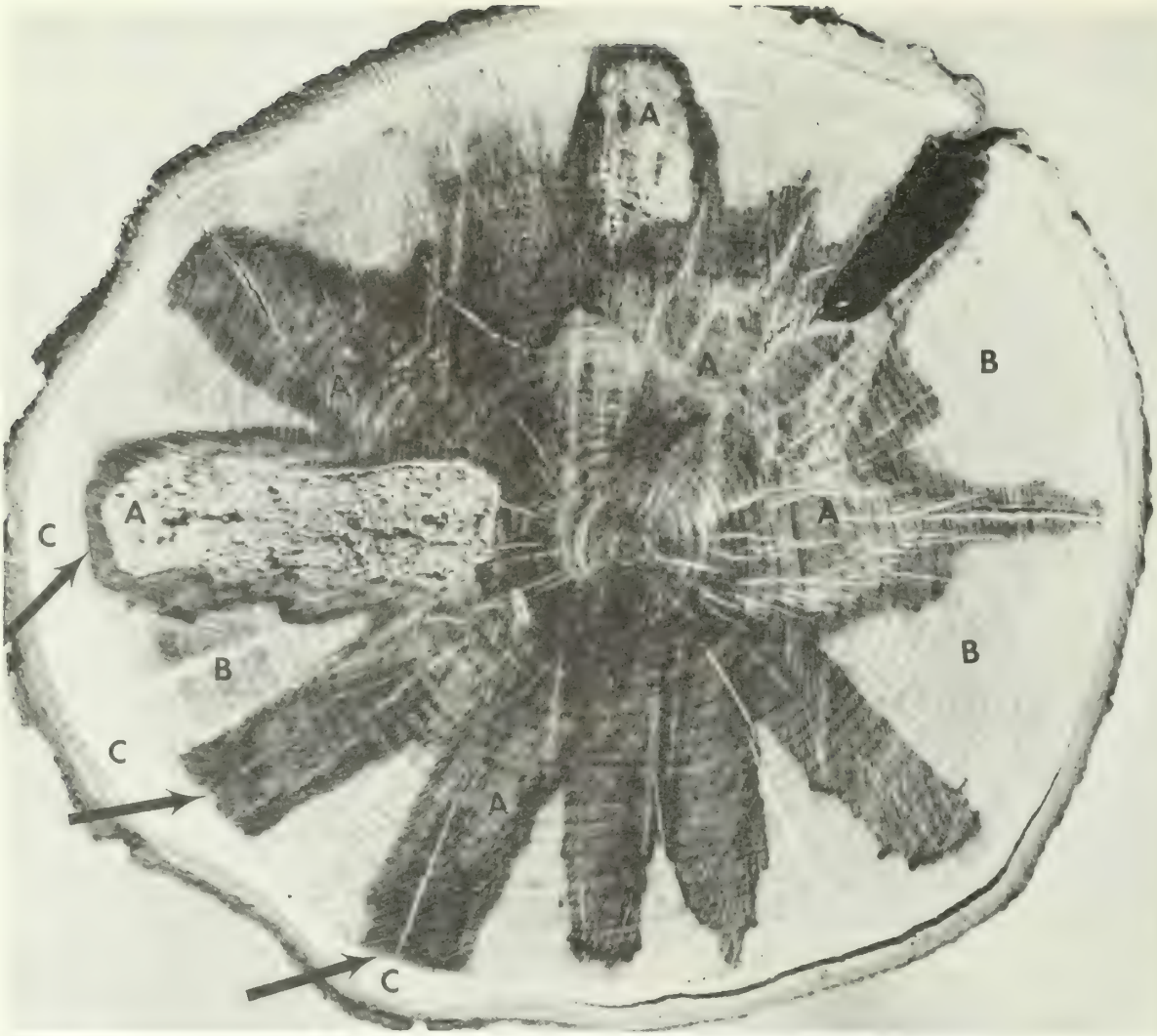



Figure 9.—This small maple was tapped excessively. Decayed wood (A) is associated with many of the tapholes. Discolored wood was associated with all tapholes. Slightly discolored wood (B) formed between the tapholes. Some of the cells in this wood have died. Arrows indicate the barrier zone that separates the wood present at the time of wounding from the tissues that formed subsequently. Healthy tissues (C) are bright white in this sample, whereas the slightly discolored tissues (B) have a pink tone. When young trees are tapped heavily, decay can set in rapidly. Decay developes in young trees just as rapidly as it does in old trees. Heavy tapping also reduces the area where new taps can be made.

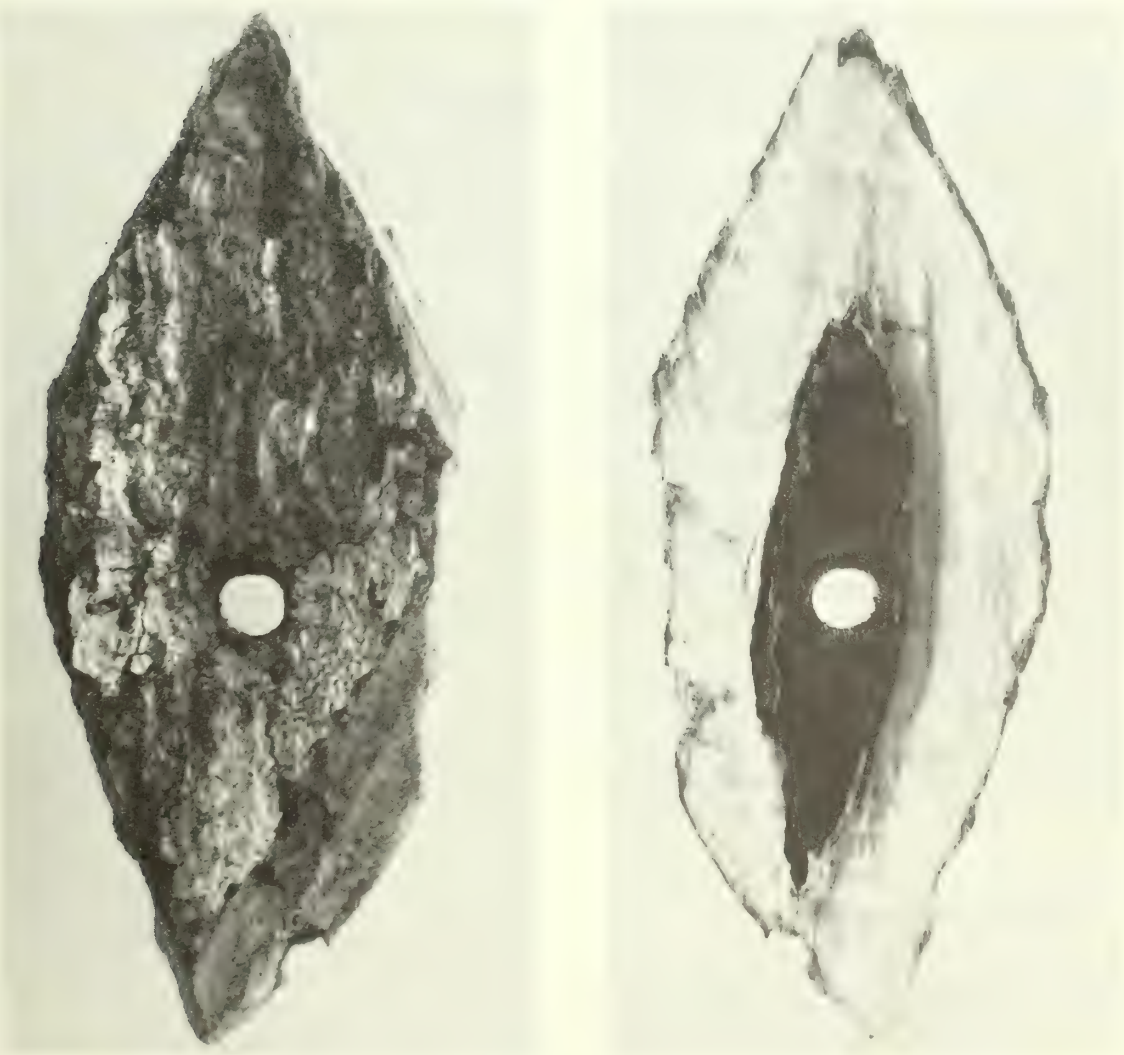
## Placing spouts

Sap collection spouts have a tapered end that is driven into the taphole. The spout must be driven in firmly enough to be seated, and secure enough to support collection buckets if they are used. The spout forms a seal that prevents sap loss, and if a plastic pipeline system is used, it prevents air leaks and vacuum loss. The spout must not be driven in so hard that it splits the bark and xylem tissue above and below the taphole. If there are splits, sap may be lost and vacuum may be difficult to maintain. The split also means that the cambial tissue around the taphole will die.

## Cambial dieback around tapholes

The cambial tissue surrounding the taphole often dies, which results in elliptical wounds (Fig. 10) much larger than the original taphole. These enlarged wounds take longer to close, and are therefore susceptible to invasion by decay-causing fungi for a longer time. In addition, the wider the wound, the greater the column width of nonproductive, dead, and discolored wood inside the tree. Another possible cause of cambial dieback is driving spouts into the tapholes when the trees are frozen.

**Figure 10.—A section of bark and wood removed from a sugar maple tree to reveal the dieback of cambial tissue as a result of tapping. Left, the bark side; right, the underside.**



## Decay begets decay

Before drilling a taphole, it is important to consider the condition of the wood. When a taphole penetrates sound wood, the injured and infected tissues will be compartmentalized. At worst, a column of rot only slightly wider than the diameter of the taphole will develop. When discolored wood is penetrated, no new column of discoloration will develop in the already discolored wood, but the clear wood surrounding the drill hole will become discolored. When a taphole penetrates decayed wood, the decay will develop rapidly outward into the newly injured tissues (Fig. 9). This means that great care should be taken when tapping trees that have obvious columns of decayed wood. If tapholes are drilled in such trees, the holes should be shallow and not enter the barrier zone surrounding the compartment of decayed wood. It is also useless to tap discolored, dead, and decayed wood. Such wood does not produce sap and may even yield water from the discolored and decayed area that will give an unwanted flavor to the syrup produced.

## Hope for injured trees

In a sense, every year a new tree, one that is unaffected by old injuries, envelops all of the other trees (growth rings) that were affected by injuries. This should be kept in mind, especially with young trees. Of course, never forget that sugar maple trees, like all other organisms, grow old and die. There is a time when little can be done to help some trees.

A tree with serious injuries may need a rest. Fewer and shallower tapholes may be good enough. But it can also mean that no tapholes should be drilled for several years. This is a small price to pay to save a tree.

A tree with a large central column of discolored and decayed wood surrounded by a narrow band of healthy whitewood can be tapped; but if the band is only 2 or 3 annual rings wide, it should not be tapped. It never hurts a tree not to drill it (Fig. 6).

## Trouble indicators

Sugar maple is one of the northern hardwoods that is most resistent to discoloration and decay. Yet there are many defective sugar maples. Besides tapholes, there are a number of other causes of injury, discoloration, and decay. These include sugar maple borers, squirrels, porcupines, sapsuckers, human activity, and natural causes. Some of the more important decay-causing fungi in sugar maples are *Oxyporus populinus* (Schum. ex Fr.) Donk, *Phellinus igniarius* (l. ex Fr.) Quél., and *Inonotus glomeratus* (Pk.) Murr. There are many external signs that indicate when a sugar maple is in trouble. Lack of a healthy, vigorous appearance; small, sparse, yellowish leaves; reduced twig elongation; and dead twigs are some of the signs. Trees with many large basal wounds, badly trampled roots, large dead branch stubs, and broken limbs will usually have a large column of discolored wood. This is not true heartwood. Normally, sugar maple does not have a dark central core of wood. Other obvious signs of trouble are fungus fruit bodies, sugar maple borer scars, and sapsucker damage.

## Wounds

Large basal wounds caused by scraping the bark from the tree and injuring the wood remain open for a long time, and often result in central discoloration and decay. These wounds often are inflicted by skidding logs and tractors. In the sugarbush they may also be caused by sap-gathering vehicles; around homes, by lawn mowers. Cattle often cause similar serious problems by trampling the tree roots and scraping the bark away from exposed roots and root collars.

Some wounds, such as branch stubs, cannot be prevented unless trees are pruned. When branches die from shading (natural pruning) and from wind and ice damage, stubs form. Falling trees and limbs may damage neighboring trees. Generally, such wounds are not serious unless they are numerous.

## Sugar maple borer

The sugar maple borer (*Glycobius speciosus*) eats through the bark of sugar maple and lives first in the cambial area and later deep in the tree. Normally, it lives in the tree for 2 years and chews a deep gallery several feet long. After the adult emerges, the bark falls away, exposing the gallery and a large wound. Decay-causing fungi often invade the wound, and many borer-damaged trees

break off in high winds. Sugar maple borers attack both healthy and low-vigor trees (Shigo and Larson 1969).

## Sapsucker wounds

The yellow-bellied sapsucker (*Sphyrapicus varius*) drills holes in sugar maple trees and other northern hardwoods. Although the small wounds cause many small streaks of discoloration, the health of the tree is not seriously impaired. But a concentrated patch of wounds is similar to one large wound, and will kill sections of the stem or the top of a tree. When such wounds encircle the tree, the entire tree will die. The discolored streaks associated with sapsucker and sugar maple borer wounds are often called mineral streaks (Shigo and Larson 1969).

## Decay-causing fungi

Any wound may be a point of infection by decay-causing fungi. The longer the wound stays open, the greater the chance of infection. An ooze flowing from a wound indicates wetwood (a type of discolored wood associated with bacteria and fungi), decay, or both. Many fungi produce conks or fruiting bodies on or near the wounds. Some of the more important fungi to look for are:

*Inonotus glomeratus* (Pk.) Murr. (*Polyporus glomeratus*). Advanced decay is indicated by small masses of sterile black fungus material in swollen knots and spindle-shaped cankers. A cut into the knot or canker will reveal the fungus as a black, cinderlike material flecked with brown areas. The decayed wood has a strong medicinal odor. Because this fungus usually infects through branch stubs, it normally is not a serious problem in the tapping zone of the tree. However, its presence in the upper part of the tree can seriously affect tree vigor and eventual sap production.

*Phellinus igniarius* (L. ex Fr.) Quél. (*Fomes igniarius*). This fungus commonly infects all northern hardwood species and causes a light-colored rot, usually with dark zone lines. The frequently seen fruit body, which is black with white flecks inside, can be found on both branch stubs and other wounds. Because this fungus infects wounds in all parts of the tree, it can cause serious problems in the tapping zone of the tree bole, as well as in the upper crown.

*Oxyporus populinus* (Schm. ex Fr.) Donk (*Fomes connatus*). The spongy white fruit body of this fungus is often found growing from a taphole. Its presence indicates advanced decay, but the decay does not extend a great distance above and below the wound unless other wounds are present. This fungus should be of special concern to the maple sugar producer because it usually infects wounds below 8 feet on the stem, i.e., in the tapping zone. Decay by this fungus can weaken trees to the extent that they are often blown over.

For additional details on defects in sugar maple trees, see Shigo and Larson (1969).

## LITERATURE CITED


Garrett, P. W., A. L. Shigo, and J. Carter.
1976. **Variation in diameter of central columns of discoloration in six hybrid poplar clone.** Can. J. For. Res. 6(4):475-477.

Gibbs, C. B.
1969. **The effect of xylem age on volume yield and sugar content of sugar maple sap.** U. S. Dep. Agric. For. Serv. Res. Pap. NE-141.

Jones, C. H., A. W. Edson, and W. J. Morse.
1903. **The maple sap flow.** Univ. Vt. Agric. Exp. Stn. Bull. 103.

Marvin, J. W.
1958. **The physiology of maple sap flow.** *In* The phsyiology of forest trees. p. 95-124. K. V. Thinman, ed. Ronald Press, New York.

Rier, J. P., and A. L. Shigo.
1972. **Some changes in red maple, *Acer rubrum,* tissues within 34 days after wounding in July.** Can. J. Bot. 50:1783-1784.

Sauter, J. J.
1974. **Maple, [a description of the mechanism of maple sap flow].** *In* McGraw-Hill Yearbook Science & Technology. p. 280-281. McGraw-Hill, New York.

Sharon, E. M.
1973. **Some histological features of *Acer saccharum* wood formed after wounding.** Can. J. For. Res. 3:83-89.

Shigo, A. L.
1976. **Compartmentalization of discolored and decayed wood in trees.** Mater. u. Org. 3:221-226.

Shigo, A. L., and W. E. Hillis.
1973. **Heartwood, discolored wood and microorganisms in living trees.** Annu. Rev. Phytophathol. 11:197-222.

Shigo, A. L., and F. M. Laing.
1970. **Some effects of paraformaldehyde on wood surrounding tapholes in sugar maple trees.** U. S. Dep. Agric. For. Serv. Res. Pap. NE-161.

Shigo, A. L., and E. vH. Larson.
1969. **A photo guide to patterns of discoloration and decay in living northern hardwood trees.** U. S. Dep. Agric. For. Serv. Res. Pap. NE-127.

Shigo, A. L., and H. G. Marx.
1977. **Compartmentalization of decay in trees.** U. S. Dep. Agric. For. Serv. Agric. Inf. Bull. 405.

Shigo, A. L., and A. Shigo.
1974. **Detection of discoloration and decay in living trees and utility poles.** U. S. Dep. Agric. For. Serv. Res. Pap. NE-294.

Shigo, A. L., W. C. Shortle, and P. W. Garrett.
1977. **Genetic control suggested in compartmentalization of discolored wood associated with tree wounds.** For. Sci. 23(2):179-182.

Shortle, W. C., T. A. Tattar, and A. E. Rich.
1971. **Effects of some phenolic compounds on the growth of *Phialophora melinii* and *Fommes connatus*.** Phytopathology 61:552-555.

Tattar, T. A., and A. E. Rich.
1973. **Extractable phenols in clear, discolored, and decayed woody tissues and bark of sugar maple and red maple.** Phytopathology 63:167-169.

Walters, R. S.
1978. **Tapholes drilled into frozen sugar maples close slowly.** U. S. Dep. Agric. For. Serv. Res. Note NE-265.

Walters, R. S., and A. L. Shigo.
1978. **Discolouration and decay associated with paraformaldehyde-treated tapholes in sugar maple.** Can. J. For. Res. 8(1):54-60.

Willits, C. O.
1958. **Maple sirup producers manual.** U. S. Dep. Agric. Agric. Handb. 134.

☆U.S. GOVERNMENT PRINTING OFFICE: 1978—703-112:55

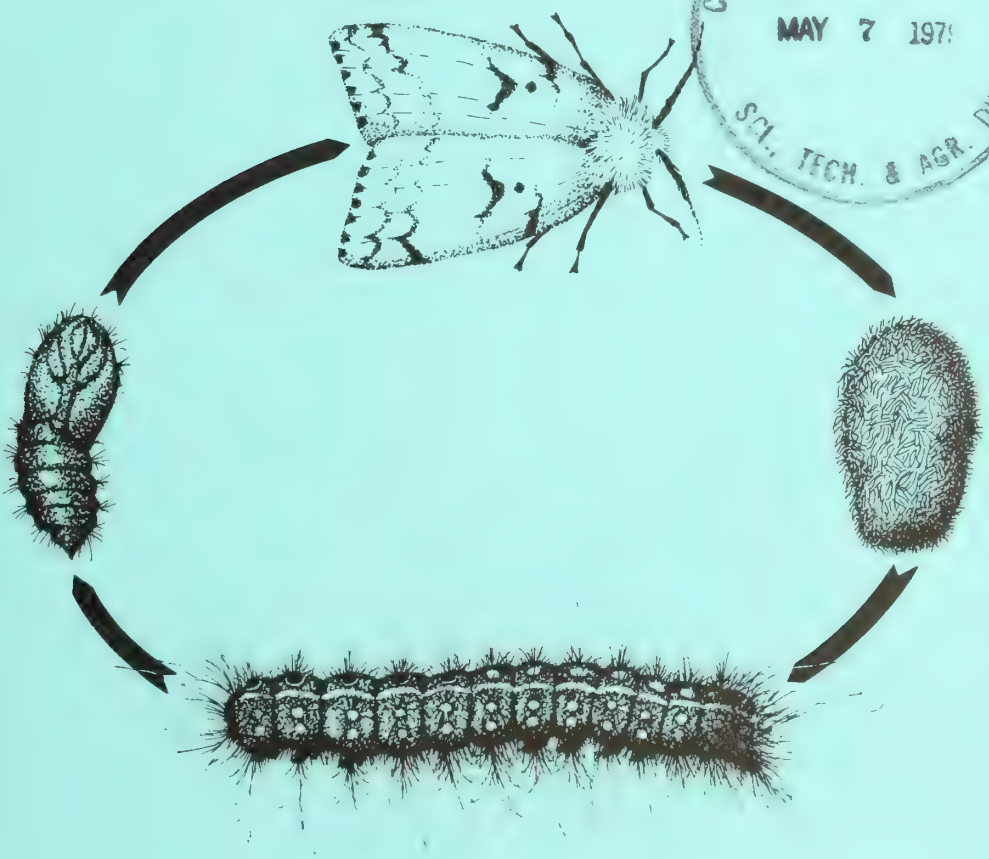
Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories and research units are maintained at:

- Beltsville, Maryland.
- Berea, Kentucky, in cooperation with Berea College.
- Burlington, Vermont, in cooperation with the University of Vermont.
- Delaware, Ohio.
- Durham, New Hampshire, in cooperation with the University of New Hampshire.
- Hamden, Connecticut, in cooperation with Yale University.
- Kingston, Pennsylvania.
- Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
- Orono, Maine, in cooperation with the University of Maine, Orono.
- Parsons, West Virginia.
- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- University Park, Pennsylvania.
- Warren, Pennsylvania.

GOVT. DOCUMENTS
DEPOSITORY
CLEMSON
LIBRARY

# POPULATION DYNAMICS OF THE GYPSY MOTH: AN ANNOTATED BIBLIOGRAPHY

CLEMSON UNIVERSITY
MAY 7 1979
SCI., TECH. & AGR. DIV.



FOREST SERVICE GENERAL TECHNICAL REPORT NE-48
1978
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
370 REED ROAD, BROOMALL, PA. 19008

## The Authors

ROBERT W. CAMPBELL is now at the Forestry Sciences Laboratory of the Pacific Northwest Forest and Range Experiment Station, Corvallis, Oreg.

LOIS C. LEVITAN is writing a book on experimental methods for gardeners.

EUGENE R. SOBECKI is teaching high school biology.

MARK F. TARDIFF is a graduate student in forest biology at the New York State College of Environmental Science and Forestry, Syracuse.

At the time this bibliography was being assembled, Campbell was on the research staff of the Northeastern Forest Experiment Station, stationed at Syracuse, N. Y., in cooperation with the Department of Forest Entomology, State University of New York, College of Environmental Science and Forestry. Levitan, Sobecki, and Tardiff were research assistants at the college.

MANUSCRIPT RECEIVED FOR PUBLICATION 15 SEPTEMBER 1978

## NOTE

The use of trade, firm or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

# POPULATION DYNAMICS OF THE GYPSY MOTH: AN ANNOTATED BIBLIOGRAPHY

BY ROBERT W. CAMPBELL
LOIS C. LEVITAN
EUGENE R. SOBECKI
MARK F. TARDIFF

**Abstract**

This annotated bibliography contains 592 references, each dealing with some aspect of the population dynamics of the gypsy moth, *Lymantria dispar* (L.).

## INTRODUCTION

THIS BIBLIOGRAPHY contains 592 references selected from the world literature on the gypsy moth, *Lymantria dispar* (L.) and related subjects. Either directly or indirectly, each of these references deals with some aspect of the dynamics of this population system.

Although scattered and fragmented, a stupendous world literature deals in some direct way with the gypsy moth. For example, we scanned the titles of at least 6000 gypsy moth related documents during our search for specific papers on its population dynamics. Although we undoubtedly failed to include many publications containing significant information, these references probably represent most of the knowledge that had accumulated about the dynamics of this life system through about 1974. Many of these references, together with a substantial number of more recent papers, have recently been reviewed.[1]

Because the total literature base on this insect is so enormous, we sought to acquire only documents that appeared relevant from their titles alone. Ultimately, we acquired nearly all of the documents we requested; primarily through the splendid efforts of the research librarians at the National Agricultural Library. For many papers in foreign languages we are able to quote from the author's English language summary or abstract. Such material is enclosed in quotation marks. However, we were unable to provide any abstract for 144 of the references. Although nomenclature in all groups has changed considerably, we made no attempt to update synonomy. Rather, we recorded names as they had appeared in the original papers.

[1] Campbell, R. W. 1979. Population dynamics: Historical review. *In* The gypsy moth: Research toward integrated pest management (M. Sommerville, Ed.) U.S. Dep. Agric. Tech. Bull. 1584. In press.

All references are cited in alphabetical order and each has been assigned a number. For example, references wherein V. I. Benkevich is the senior author are numbered 27-35.

Each reference followed by an abstract concludes with a set of key words and numbers. These key symbols, together with the number of abstracts wherein each one appears, are defined below:

| *Key word or number (meaning)* | *Number of abstracts* |
|---|---|
| Generation | 160 |
| Eggs | 107 |
| Instars I-III | 56 |
| Instars IV-VI | 34 |
| Larvae | 164 |
| Prepupae | 13 |
| Pupae | 87 |
| Adults | 43 |
| Sex ratio | 14 |
| Fecundity | 21 |
| Oak stands | 56 |
| Non-oak stands | 29 |
| All stands | 49 |
| 1 = Behavior | 93 |
| 2 = Gradation | 121 |
| 3 = Invertebrate predators | 51 |
| 4 = Parasites | 162 |
| 5 = Bacteria | 23 |
| 6 = Disease | 22 |
| 7 = Virus | 61 |
| 8 = Other infectious agents | 14 |
| 9 = Birds | 27 |
| 10 = Mammals | 17 |
| 11 = Other vertebrates | 1 |
| 12 = Environmental influence | 119 |
| 13 = Miscellaneous | 54 |
| 15 = Defoliation, gypsy moth | 97 |
| 16 = Defoliation and secondary organisms | 13 |
| 17 = Defoliation and other insects | 5 |
| 18 = Defoliation and environment | 12 |
| 19 = Stand dynamics and defoliation potential | 21 |
| 20 = Stand dynamics and species composition | 17 |
| 21 = Stand dynamics and crown structure | 6 |
| 22 = Stand dynamics and basal area | 4 |
| 23 = Tree physiology | 13 |
| 24 = Tree condition | 19 |
| 25 = Tree mortality of oak | 23 |
| 26 = Tree mortality of other species | 8 |
| 27 = Tree mortality of oak vs. other | 8 |
| 28 = Normal tree mortality | 7 |
| Subject-matter review | 9 |
| Bibliography | 6 |

Together, key words and numbers provide an aid in locating relevant literature on many relatively specific subjects within the broad heading "population dynamics." For example, reference no. 139, a paper by C. C. Doane, concludes with "Larvae:7." Thus, we categorized this paper as dealing primarily with virus among the larvae. An index to all key word pairs follows.

# Guide to References by Subject

| *Subject* | *Reference Numbers* |
|---|---|
| **Generation** | |
| Behavior | 55, 58, 59, 68, 69, 81, 92, 107, 117, 201, 225, 226, 241, 300, 302, 366, 372, 399, 403, 428, 493, 536, 586. |
| Gradation | 8, 28, 29, 30, 31, 35, 45, 49, 51, 55, 58, 69, 79, 81, 82, 89, 90, 92, 94, 95, 105, 107, 116, 117, 120, 126, 137, 149, 154, 171, 173, 175, 179, 187, 188, 190, 192, 193, 207, 213, 226, 236, 237, 239, 241, 242, 254, 257, 258, 259, 260, 268, 269, 271, 280, 299, 303, 333, 340, 341, 342, 343, 344, 345, 368, 433, 436, 439, 468, 478, 480, 494, 495, 523, 537, 538, 541, 545, 546, 547, 551, 553, 557, 558, 559, 560, 588. |
| Invertebrate predators | 18, 116, 167, 176, 193, 257, 315, 403, 521, 525, 545. |
| Parasites | 18, 40, 62, 69, 105, 116, 123, 154, 170, 171, 174, 177, 193, 230, 239, 257, 258, 260, 271, 333, 372, 400, 401, 402, 403, 414, 444, 446, 465, 478, 481, 495, 511, 519, 521, 523, 525, 545, 549, 550, 556. |
| Bacteria | 105, 143, 459, 556. |
| Diseases | 260, 269, 481, 556. |
| Viruses | 99, 105, 271, 279, 399, 428, 459, 496, 545, 556, 558, 560, 561, 570. |
| Other infectious agents | 105, 428, 459, 556, 575, 576. |
| Birds | 49, 50, 69, 119, 176, 372, 523, 532. |
| Mammals | 49, 176. |
| Environmental influence | 10, 28, 29, 30, 31, 32, 33, 34, 35, 37, 82, 90, 94, 98, 107, 137, 149, 169, 171, 175, 176, 179, 190, 201, 234, 235, 236, 239, 242, 245, 257, 258, 259, 262, 271, 280, 283, 299, 300, 303, 310, 333, 335, 338, 342, 343, 389, 424, 428, 429, 433, 493, 495, 496, 541, 545, 547, 558, 588. |
| Miscellaneous | 159, 162, 201, 245, 299, 302, 303, 424, 430, 446, 521. |
| **Eggs** | |
| Behavior | 370. |
| Gradation | 37, 70, 73, 82, 90, 129, 191, 236, 237, 239, 317, 334, 336, 343, 349, 363, 545, 589. |
| Invertebrate predators | 52, 176, 445. |
| Parasites | 17, 37, 39, 40, 41, 44, 57, 63, 64, 68, 124, 128, 129, 141, 155, 157, 169, 190, 192, 211, 227, 228, 229, 264, 269, 289, 344, 345, 355, 371, 375, 376, 393, 394, 395, 396, 397, 398, 399, 426, 436, 445, 455, 458, 459, 468, 469, 475, 497, 499, 508, 512, 513, 517, 538, 550, 577, 578, 579. |
| Virus | 99, 101, 143, 557, 563. |
| Other infectious agents | 157, 332. |
| Birds | 149, 175, 273. |
| Mammals | 175, 495. |
| Environmental influence | 37, 42, 68, 83, 90, 129, 141, 176, 212, 227, 228, 273, 311, 335, 337, 338, 339, 352, 354, 425, 461, 509, 552, 589. |
| Miscellaneous | 129, 194, 306, 310, 317, 327, 349, 354, 425, 527, 552, 589. |

**Instars I–III**

| | |
|---|---|
| Behavior | 37, 45, 54, 68, 69, 87, 96, 110, 111, 115, 120, 132, 205, 267, 273, 304, 305, 306, 307, 320, 328, 329, 363, 366, 370, 436, 479, 484, 571, 578. |
| Gradation | 92, 494. |
| Invertebrate predators | 54. |
| Parasites | 64, 125, 131, 167, 186, 247, 344, 345, 384, 385, 414, 441, 445, 447, 448, 458, 508, 554. |
| Bacteria | 21, 122. |
| Diseases | 21, 436. |
| Viruses | 143. |
| Birds | 69, 175, 186. |
| Environmental influence | 54, 68, 120, 236, 304, 305, 307, 320, 328, 329, 366, 448. |
| Miscellaneous | 315, 447, 484. |

**Instars IV–VI**

| | |
|---|---|
| Behavior | 36, 37, 68, 69, 75, 87, 304, 305, 363, 571. |
| Gradation | 36, 37, 76, 92. |
| Invertebrate predators | 36, 37, 69, 113, 191, 445. |
| Parasites | 36, 69, 93, 126, 186, 441, 445, 448, 449, 458, 459, 472. |
| Bacteria | 75. |
| Diseases | 69, 70, 71, 74, 75, 76, 77, 101, 191, 436. |
| Viruses | 69, 75. |
| Other infectious agents | 218. |
| Birds | 69, 92, 93, 94, 175, 186. |
| Mammals | 36, 37, 69, 75, 92, 93, 94. |
| Environmental influence | 36, 68, 70, 93, 94, 304, 305, 448. |
| Miscellaneous | 315. |

**Larvae**

| | |
|---|---|
| Behavior | 44, 60, 76, 87, 91, 145, 154, 175, 176, 184, 207, 240, 252, 298, 301, 307, 309, 310, 388, 542, 545, 572, 577, 585. |
| Gradation | 186, 191, 212, 237, 238, 240, 242, 280, 296, 298, 301, 310, 369, 522, 545, 564. |
| Invertebrate predators | 4, 17, 44, 52, 53, 56, 61, 63, 64, 68, 76, 112, 119, 146, 176, 207, 236, 242, 321, 393, 394, 410, 428, 497, 540, 554, 580, 581. |
| Parasites | 17, 37, 44, 63, 64, 68, 76, 91, 119, 127, 130, 151, 152, 169, 187, 191, 211, 212, 215, 228, 231, 237, 252, 269, 356, 383, 386, 387, 393, 394, 395, 396, 397, 398, 399, 428, 430, 438, 455, 468, 473, 489, 491, 494, 497, 499, 526, 547, 550, 573, 574, 578, 581, 582. |
| Bacteria | 78, 121, 122, 140, 143, 144, 145, 171, 195, 197, 206, 285, 311, 330, 438, 439, 445, 458. |
| Diseases | 78, 119, 171, 191, 438, 445, 450, 582. |
| Viruses | 4, 9, 37 44, 68, 78, 99, 101, 139, 140, 141, 145, 149, 171, 195, 196, 198, 199, 215, 228, 280, 311, 324, 330, 419, 438, 445, 450, 458, 464, 476, 494, 511, 540, 555, 557, 559, 560, 561, 563, 564, 572, 582, 583. |

Other infectious agents 332, 419, 438, 450, 458, 463.
Birds 3, 68, 91, 149, 175, 186, 187 188, 217, 436, 496, 522, 523, 531.
Mammals 68, 175, 436, 460.
Other vertebrates 176.
Environmental influence 37, 91, 141, 151, 152, 163, 175, 212, 228, 235, 249, 252, 306, 307, 309, 335, 338, 339, 365, 381, 455, 476, 542, 555, 572, 587.
Miscellaneous 67, 141, 161, 164, 176, 194, 201, 221, 249, 280, 283, 296, 304, 306, 309, 310, 338, 380, 413, 476, 527, 572.

**Prepupae**
Behavior 298, 363.
Invertebrate predators 69, 236.
Parasites 69, 72, 176, 488, 490, 491, 548.
Diseases 69, 70, 71.
Miscellaneous 249, 488.

**Pupae**
Behavior 36, 68, 87, 88, 91, 176, 545.
Gradation 37, 51, 76, 92, 191, 204, 317, 369, 545, 564.
Invertebrate predators 17, 36, 37, 44, 52, 53, 56, 61, 63, 64, 69, 112, 176, 207, 236, 393, 394, 395, 397, 399, 410, 436, 458, 497, 499, 554, 580.
Parasites 36, 64, 66, 68, 69, 71, 72, 74, 75, 76, 91, 93, 147, 153, 169, 176, 191, 211, 215, 228, 269, 295, 297, 308, 356, 386, 393, 395, 396, 397, 399, 430, 436, 445, 455, 458, 459, 488, 490, 491, 497, 498, 515, 548, 550, 578.
Diseases 69, 71, 76, 77, 191.
Viruses 215, 297, 308, 557.
Other infectious agents 332.
Birds 175, 496.
Mammals 36, 37, 51, 68, 69, 75, 91, 92, 93, 94, 176, 460, 496.
Environmental influence 36, 88, 91, 93, 94, 147, 228, 261, 297, 339, 485, 587.
Miscellaneous 194, 249, 261, 296, 317, 327, 485, 488, 527.

**Adults**
Behavior 27, 68, 97, 114, 142, 148, 176, 201, 204, 221, 223, 252, 265, 266, 267, 273, 340, 341, 363, 365, 452, 453, 454, 471, 553, 577, 578.
Gradation 37, 88 ,173, 221, 267, 336, 340, 341.
Invertebrate predators 176, 242, 580.
Viruses 140, 557.
Birds 44, 175, 176, 212.
Mammals 176.
Other vetebrates 176.

Environmental influence 27, 201, 223, 265, 266, 339, 365, 379.
Miscellaneous 114, 194, 340, 341, 379, 452, 511, 527, 577.

**Sex ratio**
Gradation 37, 71, 176, 239, 490, 543, 545.
Parasites 41, 69, 71, 74, 543.
Diseases 69, 71, 74, 436, 450.
Viruses 543.
Mammals 93.
Environmental influence 543.
Miscellaneous 338.

**Fecundity**
Behavior 142.
Gradation 137, 148, 175, 239, 241, 317, 327, 369, 545, 553.
Environmental influence 42, 69, 175, 235, 236, 242, 309, 338, 339.
Miscellaneous 137, 161, 317, 327, 338, 527.

**Oak stands**
Defoliation and gypsy moth 5, 7, 18, 20, 36, 44, 46, 73, 80, 84, 85, 95, 106, 118, 137, 149, 158, 162, 171, 178, 179, 211, 224, 238, 249, 253, 254, 255, 257, 294, 308, 331, 353, 368, 405, 413, 451, 455, 458, 491, 492, 494, 533, 541, 567, 587.
Defoliation and secondary organisms 95, 106, 158, 211, 224, 253, 255, 294, 405, 492, 502.
Defoliation and other insects 7, 251, 502, 567.
Defoliation and environment 7, 189, 224, 251, 405, 502.
Stand dynamics and defoliation potential 24, 73, 80, 95, 179, 367, 413, 494, 567, 587.
Stand dynamics and species composition 24, 80, 84, 95, 179, 253, 255, 404, 541.
Stand dynamics and crown structure 84, 95, 118, 255, 405.
Stand dynamics and basal area 95, 251, 253, 255.
Tree physiology 5, 224, 280, 294, 413, 502, 542, 567.
Tree condition 80, 95, 178, 179, 251, 253, 255, 331, 367, 368, 405, 492, 496, 533, 534.
Tree mortality of oak 7, 20, 80, 95, 106, 158, 179, 224, 251, 253, 254, 255, 294, 367, 404, 405, 451, 458, 492, 502, 541.

Tree mortality of other species 80, 95.
Tree mortality of oak vs. other 80, 95, 253, 255, 404.
Normal tree mortality 95, 253, 254, 255.

**Non-oak stands**
Defoliation and gypsy moth 20, 46, 106, 149, 163, 187, 191, 205, 214, 236, 249, 252, 258, 259, 267, 287, 311, 323, 344, 345, 427, 444, 470, 484, 495, 534.
Defoliation and environment 252.
Stand dynamics and defoliation potential 214.
Tree physiology 67, 542.
Tree condition 118, 534.
Tree mortality of other species 214, 534.

**All stands**
Defoliation and gypsy moth 19, 23, 25, 45, 55, 59, 60, 68, 69, 95, 106, 107, 120, 154, 161, 171, 176, 211, 238, 257, 286, 322, 361, 363, 366, 377, 381, 399, 400, 401, 403, 480, 496, 500, 506, 507, 541.
Defoliation and secondary organisms 20, 95, 208.
Defoliation and other insects 208.
Defoliation and environment 120, 149, 322, 496, 500.
Stand dynamics and defoliation potential 23, 24, 25, 37, 95, 171, 203, 259, 322, 388, 500, 507.
Stand dynamics and species composition 24, 25, 69, 95, 107, 118, 172, 203, 322, 500, 541.
Stand dynamics and crown structure 95, 500.

Stand dynamics
and basal area 95.
Tree physiology 257, 277, 280, 361, 507.
Tree condition 95, 120, 286, 361.
Tree mortality
of oak 95, 286, 377, 541.
Tree mortality
of other species 95, 120, 286, 377, 541.
Tree mortality
of oak vs. other 20, 95, 506, 507.
Normal tree
mortality 95, 496, 506, 507.

**Review papers** 47, 65, 86, 168, 181, 286, 312, 474, 535.

**Bibliographies** 180, 216, 286, 312, 474, 535.

1. Abdullaev, E.
1966. **Egg parasites of the gypsy moth *(Lymantria dispar L.)* in Samarkand** [in Russian, Uzbek summary]. Uzb. Biol. Zh. 1966 (4): 57–60.

2. Abdullaev, E.
1967. **Parasites of eggs of the gypsy moth *(Lymantria dispar L.)* (Orgyidae; Lepidoptera) according to findings from Samarkand Region** [in Russian]. Pages 25–29 *in* Academiya Nauk. Uzbebskoi SSR institut zoologii i Barazitologii. Poleznye i Vrednye bespozvonochnye Zhivotnye, Uzbekistan.

3. Allen, A.A.
1917. **The warblers**. Am. For. 23: 221–225
Warblers are primarily woodland birds. They arrive in the early spring when gypsy moth eggs are hatching, and they practically rid the trees of insect pests. Warblers do not like the large, full-grown, hairy larvae, but "they destroy them while they are small in great numbers."
**Larvae: 9**

4. Allen, H.W.
1916. **Notes on the relation of insects to the spread of the wilt disease.** J. Econ. Entomol. 9: 233–235.
Scavengers of gypsy moth larvae were examined for the presence of polyhedral inclusion bodies. Sarcophagid adults and *Calosoma sycophanta* larvae were found to carry polyhedra. It is evident that wilt is not primarily a windborne disease. The insects that frequent the foliage of trees "carry polyhedra, after contact with the wilt, which indicates that they may assist in spreading the infection."
**Larvae: 3,7**

5. Amirkhanova, S.N.
1962. **Nutrient substances in the leaves of healthy and weakened food plants for the gypsy moth** [in Russian]. Pages 81–95 *in* Issledovaniya ochagov vreditelei lesa Bashkirii, UFA Vol. II.
Studies were made of the chemical composition of oak leaves from trees that were healthy, diseased, or weakened by root banding. The leaves were fed to gypsy moth caterpillars. At first there was an increase in dry matter, oil, soluble sugars, starch, and cellulose, and a decrease in the relative content of protein and phosphorus. During the summer when the leaves were fully developed, all the basic substances kept at a constant level, except for starch, which tended to decrease. Warm, moist vegetative periods caused increases in the foliar content of oil, soluble sugars, and starch. The sugar content increased in warmer, drier years. Banding the trunk and cutting slits in the roots caused increases in the foliar content of proteins, soluble sugars, and starch, which are the same changes that usually occur in the development of oak leaves in arid years.
**Oak stands: 15,23**

6. Anasiewicz, A.
1964. **Observations on the appearance of *Lymantria dispar L.* on the currant bushes *Ribes nigrum L.* and *Ribes rubrum L.*** [in Polish, Russian and French summaries]. An. Univ. Mariae Curie-Sklodowska Sec. C. 19(7): 111–118.

7. Anderson, J.F., and S.W. Gould
1974. **Defoliation in Connecticut, 1969–1974: tabulated by use of the geo-code.** Conn. Agric. Exp. Stn. Bull. 749. 25 p.
"High tree mortality, particularly among oaks, may occur in several areas where severe defoliation has occurred for two or more successive years on sites with shallow, rocky soils."
**Oak stands: 15,17,18,25**

8. Anon.
1890. **The imported gipsy moth *(Ocneria dispar L.)*.** Insect Life 2: 208–211.
The gypsy moth was present in restricted areas in Massachusetts from 1870 to 1890, but it was not a pest until 1889 and was not recorded in collections or checklists. It was generally held in check in Europe by natural enemies but occasionally was very destructive: for example, in 1817 on the cork oak in southern France, in 1878 on the plane trees of the public promenade in Lyons, and in 1889 at the Berlin zoo.
**Generation: 2**

9. Aratake, Y. and T. Kayamura.
1972. **Cross transmission of polyhedrosis viruses of the gypsy moth, *Lymantria dispar japonica* Motschulsky, to the silkworm, *Bombyx mori L.*, and other lepidopterous insects** [in Japanese, English summary]. Proc. Assoc. Plant Prot. Kyushu 18:17–20.

"A nuclear polyhedrosis virus (NPV) of the gypsy moth, *Lymantria dispar japonica*, was not infectious to the silkworm, *Bombyx mori*, and other seven species of lepidopterous insects, but [was] infectious to three species: *Euproctis similis, Dendrolimus spectabilis,* and *Clostera anastomosis.* On the other hand, a cytoplasmic polyhedrosis virus (CPV) of *L. dispar* showed a wider host range compared with the *Lymantria* NPV, infecting *B. mori, E. similis, D. spectabilis, C. anastomosis, Malacosoma neustria testacea, Lymantria mathura aurora, Philosamia cynthia pryeri, Dictyoploca japonica, Scopelodes contracta,* and *Arcte coerulea.* A *Lymantria* CPV retained the infectivity to *B. mori* after a passage through the alternate hosts: *E. similis, P. cynthia pryeri, S. contracta, C. anastomosis, M. neustria testacea,* and *L. mathura aurora.* A *Lymantria* CPV was still infectious to the original host after several passages through *B mori*, but it took a longer incubation period of lethal infection than the original *Lymantria* CPV."
**Larvae: 7**

10. Ashworth, J.T., and R.B. Friend
1944. **Gypsy moth control**. Pages 253–256 *in* Conn. State Entomol., 1943, 43rd rep. Conn. Agric. Exp. Stn. Bull. 481.

The low gypsy moth populations in the winters of 1940–41 and 1942–43 are attributed to low temperatures (down to -23°F). "In the winter of 1939–40 the number of egg masses per acre in eight one-acre plots varied from 299 to 1403. In the winter of 1940–41 the number on seven adjacent one-acre plots varied from three to nine per acre; in the winter of 1942–43, on the same seven plots, from zero to seven per acre; and in the winter of 1943–44, from zero to three per acre."
**Generation: 12**

11. Atger, P.
1963. **The diseases of *Lymantria dispar* and the possibilities of microbiological control against this insect** [in French, German summary]. Rev. Pathol. Veg. Entomol. Agric. Fr. 42(1): 47–51.

12. Aulló, M.
1922. **Acclimatization of parasitic insects** [in Spanish]. Rev. Montes 46: 519–521.

13. Aulló, M.
1926. **Organization of campaigns to eradicate *Lymantria dispar* L. outbreaks** [in Spanish]. Rev. Fitopatol. 2–3: 5–12.

14. Aulló y Costilla, M.
1929. **Study of an outbreak of *Lymantria dispar* L. in the oaks of Pedroches Valley (Cordoba)** [in Spanish]. Rev. Fitopatol. 4–6(6): 3–5.

15. Baer, W.
1920. **Tachinids as parasites of injurious insects: their life history, economic importance, and systematic characters** [in German]. Z. Angew. Entomol. 6(2): 185–246.

16. Baeta Neves, C.M.
1942–1943. **The distinction between *Lymantria dispar* L. and other pests that attack cork oak** [in Portuguese]. Bol. Junta Nac. çortica (Lisbon) 50–51: 49–53, 97–101.

17. Baeta Neves, C.M., and F. Azevedo E. Silva.
1944. **Notes on the application of biological control in the campaign against *Lymantria*** [in Portuguese]. Bol. Junta Nac. Çortica (Lisbon) 63: 101–103.

The gypsy moth in Portugal is reviewed, including information on introduced parasites there and in the United States. A list of parasites and predators in Portugal is given. Invertebrate predators are *Calosoma inquisitor*, L., *C. sycophanta*, L., and *Dermestes lardarius*, L. Larval parasites are *Apanteles melanoscelus* Ratz., *A. porthetriae* Mues., *Brachymeria intermedia* Nees, *Compsilura concinnata* Meigen, *Sturmia scutellata* Robineau-Desvoidy, *Tachina larvarum* L. and *Tricholyga segregata* Rondani. *Schedius (Ooencyrtus) kuvanae* Howard is an egg parasite.
**Eggs: 4; Larvae: 3,4; Pupae: 3**

18. Baeta Neves, C.M.
1947. **The principal insects that attack the cork oak in Portugal** [in Spanish]. Montes 3: 140–147.

The place of the cork oak (alcornoque) in the ecology and economy of Portugal is discussed. Because of the economic value of cork and acorns, they are cultivated, pruned, and treated like fruit trees. This has made the tree dominant over wide areas, which it would not be under natural conditions. In this monoculture the gypsy moth can

flourish for many years. The attacked area is a region between the Sado and the Sorraia, extending through a zone of almost 100,000 hectares of woodland. The gypsy moth was first identified in Portugal in 1886 in Obidos (Estremadora). The following are indiginous parasites and predators: *Calosoma sycophanta, Dermestes lardarius* L., *Compsilura concinnata* Meigen, *Sturmia scutellata* Rob. Des., *Brachymeria intermedia* Nees, and *Apanteles* sp. Although *Schedius kuwanae* was introduced and released, it did not control the infestation. This failure is blamed on insufficient release.
**Oak stands: 15; Generation: 3,4**

19. Baker, W.L., and A.C. Cline.
1936. **A study of the gypsy moth in the town of Petersham, Mass., in 1935.** J. For. 34: 759–765.
"Complete defoliation was not observed in any instance where favored food trees constituted less than 50 percent of the stand. In 56 out of 81 defoliated areas, oak, gray birch, and poplar comprised more than 75 percent of the stand . . ."
**All stands: 15**

20. Baker, W.L.
1941. **Effect of gypsy moth defoliation on certain forest trees.** J. For. 39: 1017–1022.
"To determine economic injury by the gypsy moth to forest trees in the New England States, records of defoliation, death of trees, and loss of diameter increment were collected from trees in a wide series of plots from 1912 to 1921. Data from the oaks and white pine (species suffering greatest economic injury) show that an increase in average defoliation was associated in general with an increase in mortality. Growth and defoliation data of four species of oaks and white pine show a direct correlation between percentage of defoliation and decline in radial increment. Diameter growth of black, white, and scarlet oaks was found to fluctuate inversely with percent[age] of defoliation the same year defoliation occurred. In young white pines defoliated only once, there was direct correlation between percent[age] of defoliation and percent[age] of trees dying during the following 9-year period. . . . . This killing may not be entirely a result of defoliation but may be associated with the development of secondary agencies in the weakened trees. From 1912 to 1915 an outbreak of two-lined chestnut borer (*Agrilus bilineatus* (Web.)), developed in the oaks in eastern New England and may have hastened the death of great numbers of trees weakened by heavy defoliation and drought. The shoe-string fungus (*Armillaria mellea* (Vahl.) Quil.) may also have attacked and hastened the death of weakened trees."
**Oak stands: 15,25; All stands: 16,27; Non-oak stands: 15**

21. Barnes, D.F., and S.F. Potts.
1929. **A disease differing from wilt observed in gipsy moth larvae.** J. Econ. Entomol. 22: 423.
Toxicity tests with lead arsenate were conducted on gypsy moth larvae. When the larvae reached the third instar, a heavy mortality occurred which could not be attributed either to the poison or to polyhedral disease. *Streptococcus disparis* was suspected as the cause of death.
**Instars** I–III: **5,6**

22. Barsacq, J.
1913. **The gypsy moth (*Lymantria (Ocneria) dispar* L.)** [in French]. Rev. Phytopathol. Appl. 1(5): 70–73.

23. Behre, C. E. A.C. Cline, and W.L. Baker.
1936. **Silvicultural control of the gypsy moth.** Mass. For. Park Assoc. Bull. 157. 16 p.
"The forest types which present most favorable conditions for gypsy moth attack are the direct result of a transient agriculture and the destructive lumbering practices of the past." The gypsy moth prefers light-demanding weed species which come in after clearcutting has taken place or farmland has been abandoned. Forest types in the Northeast are discussed in relation to susceptibility to the gypsy moth. The Northern Hardwood Forest is resistant primarily as the result of climate. The Central Hardwood Region of southern New England is composed largely of favored species, yet epidemics have been prevented by some factor other than food. The Cape Cod Region, with sandy soils and an equable climate, bears pitch pine and scrub oak and has been subject to frequent severe outbreaks. The White Pine Region has been the most severely hit area. Its forests are dominated by white pine only on light, sandy soils; otherwise trees of the Central Hardwood Region predominate, making it a transition forest zone.
**All stands: 15,19**

24. Behre, C. E.
1939. **The opportunity for forestry practice in the control of gypsy moth in Massachusetts woodlands.** J. For. 37: 546–551.

Surveys were made that assigned almost 100,000 acres of Massachusetts forests to one of five categories with respect to resistance to gypsy moth attack. Differentiation was based on percentage of favored food species in the stand. In western Massachusetts 75 percent of the plots were classified as fully or dominantly resistant. In the pine-oak region about half the forested area was entirely or dominantly occupied by highly favored food species. Selected cutting of favored food species is recommended, and partial cutting is advocated in place of clearcutting.

**All stands: 19,20; Oak stands: 19,20**

25. Behre, C. E., and L. H. Reineke.
1943. **The opportunity for silvicultural control of gypsy moth in southwestern Maine.** J. For. 41:811–815.

A list of forest types in southwestern Maine is given with their relative susceptibility to gypsy moth infestation. Priorities are listed with reference to desirability of silvicultural treatment, based on economic value, damage, susceptibility, and treatments required. The main method of control is the establishment of resistant species of trees by cutting and pruning the preferred food class species.

**All stands: 15, 19, 20**

26. Bei-Bienko, G.
1924. **Notes on the biology of *Lymantria dispar* L. on the Altai mountains** [in Russian]. Proc. Sib. Agric. Acad. 3: 155–160.

27. Benkevich, V. I.
1958. **Various tree species and their age groups as a substrate for oviposition of the gypsy moth *(Porthetria dispar*,** [in Russian]. Nauchn. Dokl. Vyssh. Shk. Biol. Nauk. 4: 26–30.

A survey was made in the forests near Moscow of tree species, age classes, and amount of gypsy moth oviposition. Trunks of old oak and spruce and young birch, linden, larch, and pine were preferred by the gypsy moth, especially those trees with a southern or eastern exposure in a sparse, parklike planting. Spruce, birch, larch, pine, and linden (in ascending order) were the most vulnerable to gypsy moth infestation. The lower the humidity of the soil under these species, the more they are infested. Underbrush and grass stands, however, lower the degree of infestation.

**Adults: 1,12**

28. Benkevich, V. I.
1961. **Data on the prediction of the mass emergence of the gypsy moth, *Porthetria dispar*. Communication I. The mass emergence of the gypsy moth and its prediction in Moscow region** [in Russian]. Pages 22–29 *in* Works on animal ecology and taxonomy of the Orekhovo-Zuevskogo Teachers Institute, vol. 2.

Gypsy moth outbreak was preceded by several years of severe, dry winters. For 3 years before the population eruption, the weather in May and June, when the larvae fed, was hot and dry.

**Generation: 2,12**

29. Benkevich, V. I.
1961. **Data on the prediction of the mass emergence of the gypsy moth *Porthetria dispar*. II. The mass emergence of the gypsy moth and its prediction in the lower Volga River Valley.** [in Russian]. Pages 38–40 *in* Works on animal ecology and taxonomy of the Orekhovo-Zuevskogo Teachers Institute, vol. 2.

Gypsy moth outbreak is preceded for a period of 4 to 5 years by special meteorological conditions: (1) for 3 or 4 years before the outbreak, the index of severity of the winter is almost always higher than the mean perennial values, while the mean temperature of the coldest month is very low; (2) for 3 years before the outbreak the hydrothermal index for May and June is usually much lower than the mean perennial values; and (3) severe winters and dry, hot weather in May and June are repeated for not less than 2 successive years during the preliminary period. Deviations of meteorological factors from the norm do not cause a mass emergence of the gypsy moth.

**Generation: 2,12**

30. Benkevich, V. I.
1961. **Materials towards forecasting outbreaks of *Ocneria dispar* L. III. Outbreaks of *O. dispar* L. and their forecast in the Ul'yanovskaya oblast' and the Bashkir Autonomous SSR (Studies in ecology and classification of animals)** [in Russian]. Orekhovo-Zuevskogo Pedagog. Inst. Moskva 2: 45–59.

Typically, winters in the Ul'yanovskaya region and the Bashkir Autonomous SSR are mild. How-

ever, the 3 or 4 winters preceding gypsy moth outbreak are severe, with a low mean temperature during the coldest month. Up to 3 years prior to an outbreak, larval development proceeds under normal conditions, or perhaps with a dry May and June. Two years before the outbreak, the humidity in May and June is typically higher and near normal.
**Generation: 2,12**

31. Benkevich, V. I.
1962. **Forecasting the mass emergence of the gypsy moth, *Ocneria dispar* L. (Lepidoptera, Liparidae). IV. Forecasting emergences of the moth in eastern Siberia.** Entomol. Rev. (English transl. Entomol. Obozr.) 41: 22–27.

Meteorological data from four provinces of eastern Siberia (Chita, Irkutsk, Buryat SSSR, and Ruva ASSR) were analyzed to determine the conditions that initiate a mass outbreak of the gypsy moth. Tables are given comparing the environmental conditions that prevailed in the 5–, 4–, and 3–year intervals between mass outbreaks. The gypsy moth population was not affected positively by separate ecological factors but by these factors in combination. The hydrothermal conditions over a period of 5 successive years were very important. It appears that a 5-year preparatory period is required before such outbreaks can occur, during which time the pest population grows.
**Generation: 2,12**

32. Benkevich, V. I.
1963. **Data on forecasting the large-scale appearance of *Ocneria dispar* (Lepidoptera: Liparidae). V. Forecasts of the large-scale appearances of *Ocneria dispar* in Voronezh** [in Russian]. Nauchn. Dokl. Vyssh. Shk. Biol. Nauk. 1: 17–22.

Outbreaks of *O. dispar* depend on a number of ecological factors. Meteorological conditions (mainly water and heat balance) for 5 successive years were the most important: (a) drought in May and June for 3 years before outbreaks; (b) very severe winters for 3 or 4 years before outbreaks; and (c) low values of the "hydrothermal coefficient." This includes the average temperature of the coldest month plus high (rarely close to normal) values of coefficients of severity of the entire winter (and of the first half of the winter) for not less than 2 successive years of the total 5-year period preceding a large-scale outbreak.
**Generation: 12**

33. Benkevich, V. I., and I. A. Nazarov.
1964. **Information on the forecast of the widespread appearance of *Ocneria dispar* (Lepidoptera, Liparidae). VI. Widespread appearance of *Ocneria dispar* and its forecast in Ryazan Oblast.** [in Russian]. Orekhovo-Zuevskogo. Inst. 3: 28–66.

Studies of the hydrothermal regime and the population dynamics of the gypsy moth revealed diminished or minimal solar activity for 5 years before the outbreak. For 3 years there were hot, dry summers with a low hydrothermal coefficient in May and June. Low values of the hydrothermal coefficient, average temperatures of the coldest month, and high severity coefficients in the preparatory period were observed for not less than 2 successive years. A very cold May for 2 years before drought may eliminate the possibility of the widespread appearance of *O. dispar*. An entire complex of ecological conditions affects the population size of *O. dispar*, but meteorological factors in the period preceding their emergence are the most important determinants. A bibliography with 36 references is included.
**Generation: 12**

34. Benkevich, V.I.
1964. **Information on the forecast of the widespread appearance of *Ocneria dispar* (Lepidoptera, Liparidae). VII. Widespread appearance of *Ocneria dispar* and their forecast in the forest of the Crimea** [in Russian]. Tr. Orekhovo-Zuevskogo Pedagog Inst. 3: 67–82.

For 3 or 4 years prior to gypsy moth outbreak there had been relatively cold winters, with one very cold month; for 3 years there had been dry weather from May to August; and for 1 year, even the year when the insects appeared on a large scale, there had always been a decline in solar activity. A bibliography with 51 references is included.
**Generation: 12**

35. Benkevich, V. I.
1964. **Information on the forecast of the widespread appearance of *Ocneria dispar* (Lepidoptera, Liparidae). VIII. The widespread appearance of *Ocneria dispar* and their forecast in the**

**forests of Altai Krai in eastern Kazakhstan** [in Russian]. Tr. Orekhovo-Zuevskogo Pedagog. Inst. 3: 83–95.

Studies were made of the hydrothermal regime preceding outbreak of *Ocneria dispar*. For 3 or 4 years prior to the outbreak there had been cold, severe winters, and for 3 years before the outbreak there had been droughts in May and June.

**Generation: 2, 12**

36. Bess, H. A.
1947. **I. Relation of forest and site to gypsy moth abundance.** Pages 7–26 in H. A. Bess, S. H. Spurr, and E. W. Littlefield. Forest site conditions, Forest site conditions and the gypsy moth. Harv. For. Bull. 22. Petersham, Mass.

This is a summary of ecological studies on the gypsy moth initiated in 1937 by the U.S. Department of Agriculture, Division of Forest Insect Investigation of the Bureau of Entomology and Plant Quarantine. The information obtained indicates that gypsy moth abundance is strongly influenced by forest and site conditions. Larval behavior differs under different site conditions, with survival lower and defoliation slight where large larvae are found in the litter during the daytime. Larvae tend to remain in the tree under xerophytic site conditions and to rest in the litter under mesophytic conditions. To find out if small mammals (whose populations are highest in dense forest stands with moist, deep ground cover) are responsible for mortality of larvae on the ground, tests were run using cages that excluded them. The results indicated strongly that they are a major mortality factor. The short- tailed shrew and the deer mouse, both voracious insect eaters, were the most abundant small mammals in a good hardwood stand in Petersham, Mass., where no defoliation occurred during the period of census trapping, although larvae were observed.

To determine if predators could cope with large numbers of larvae, different quantities of larvae were released under equivalent site conditions. There was some evidence that survival was higher with larger liberations. Prolonged hot, dry weather during larval and pupal periods helps to maintain a high population level. The same conditions brought about by drought are created by land abuse, e.g., clearcutting, forest fires, and woodlot grazing. Late spring drought in one season followed by early spring drought the next brings about a great increase in population. In a 2-year period these conditions were encountered twice, in 1935–1936 and 1943–1944, which were the only times of heavy defoliation in Petersham.

Gypsy moth survival is high in partially defoliated stands where large larvae are likely to stay up in the trees, while litter-inhabiting predators are likely to be driven out or to decrease in number owing to the hot, dry condition of the forest floor. Thus, in its epidemic state the moth creates conditions favorable to its own survival.

**Instars** IV–VI: **1, 2, 3, 4, 10, 12. Pupae: 1, 3, 4, 10, 12; Oak stands: 15**

37. Bess, H. A.
1961. **Population ecology of the gypsy moth *Porthetria dispar* (L.) (Lepidoptera: Lymantriidae).** Conn. Agric. Exp. Stn. Bull. 646. 43 p.

This is an analysis of studies conducted between 1937 and 1945 in a wide range of woodland conditions in Massachusetts, Connecticut, and eastern New York. Primary plots were in Petersham in central Massachusetts, where there was a 30-year endemic population, and in Freetown in southeastern Massachusetts, where there had been widespread defoliation for 20 years.

Behavior and mortality factors are discussed. Among abiotic mortality factors, low temperatures in fall and spring are generally more consequential than in midwinter, although in the course of the study subzero midwinter weather caused the only extensive egg mortality. At temperatures slightly below zero, relative elevation and air drainage are important—there is a higher mortality in low frost pockets. At low temperatures, the mortality of parasitic larvae overwintering in gypsy moth eggs is higher than that of gypsy moth larvae. Heavy spring rains may wash away eggs and young larvae.

Inherent weaknesses in the species cause mortality: about 5 percent of embryos fail to develop; blockages develop in the larval alimentary canal, and larvae fail to complete molt. Additional hazards include those associated with spin-down of small larvae, larvae dropping in areas without food, larvae dropping from trees owing to wind, larvae breaking diapause too early and dying from cold or starvation, and larvae hatching in the fall. The behavioral pattern of large larvae spending the day in the litter, which abounds with predators, also contributes to mortality.

Egg mortality was 30 to 40 percent in Freetown between 1938 and 1942 and 20 percent in Petersham

(except for 1938 when it was 7 to 8 percent). Except for high localized mortality in the spring of 1943, mortality was always less than 50 percent. *Anastatus disparis* Ruschka is a relatively hardy parasite, abundant in Freetown but varying greatly in numbers in Petersham and colder regions. *Ooencyrtus kuwanae* (Howard) is widely distributed but less coldhardy. Together they parasitized between 17 and 37 percent in Freetown, except in the year after extreme winter kill (7 percent). The following year, 30 percent were parasitized. Productivity of egg parasites was directly related to the number of host eggs, but there was no relationship between percentage of parasitism and host egg population density. Where the gypsy moth population was at a low level for 3 years and parasites developed primarily on the gypsy moth, egg parasitism was at its highest level.

Larvae rest in concealed places and molt there. In early instars, suitable resting places are found under loose bark on twigs and on the underside of leaves. In good mesophytic hardwoods, large larvae descend from trees at dawn and rest in litter, but they will also rest in suitable places above the forest floor. Also, in open, dry woodlands without litter or where litter is exposed to hot sun, larvae will stay up in the trees, generally on foliage. In Petersham in 1937, larvae feeding on aspen (*Populus grandidentata* and *P. tremuloides*) were more heavily infected with wilt than those feeding on oak. Epizootics of wilt were inconsequential where food was plentiful.

There are many casual predators of the gypsy moth. *Calosoma sycophanta* and *C. frigidum* will consume gypsy moth even under low population densities when larvae congregate in litter. Thus, large larvae are very vulnerable when scarce. *Calosoma* are not found in light, sandy soils because their burrowing tunnels collapse. There is mammalian predation by the short-tail shrew (*Blarina brevicauda brevicauda* (Say)) and the deer mouse (*Peromyscus leucopus noveboracensis* (Fischer)) which are more abundant in mesophytic woodlands around Petersham than in Freetown. Gypsy moth is more abundant in Freetown; therefore, the general abundance of predators is not directly related to the general abundance of moths. When larvae are kept on tree boles and mammals are excluded, mortality decreases.

Major larval parasites are *Apanteles melanoscelus* Ratzeburg, found in more than 50 percent of gypsy moth larvae on June 29, 1938 in Freetown; *Sturmia scutellata* Robineau-Desvoidy, widespread but not in xerophytic areas; and *Compsilura concinnata* Meigen, more abundant in mesophytic forests where it has parasitized a maximum of 80 percent. The first two are almost exclusively parasites of gypsy moth, while *Compsilura* has many hosts. *Theronia fulvescens* Cresson is native and has parasitized 18 percent in one plot, but neither this nor the other species is important in control.

The percentage of larvae parasitized in an area varies widely from year to year. Instars V and VI are the most hazardous stages. Mortality correlates inversely with adult and egg populations produced; no correlation with other stages was found. Parasites do not seem as important as predators. Pupal mortality is lower in percentage and number than larval, and adult female mortality is very low prior to oviposition. All egg masses were fertile, indicating that there were sufficient males. However, sex ratio varied widely from 3:1 to 1:6 as determined from pupae (female:male). High crown density and deep litter within forests are conductive to a rich fauna, including predators.

**Adults: 2; All stands: 19; Eggs: 2, 4, 12; Generation: 12; Instars** I–III: **1; Instars** IV–VI: **1, 2, 3, 10; Larvae: 4, 7, 12; Pupae: 2, 3, 10; Sex ratio: 2**

38. Bialaszewicz, K.
1933. **Research on the chemical metabolism and energy in the course of insect development. I. Thermogenesis during the period of larval growth and metamorphosis of *Lymantria dispar* L.** [in French]. Arch. Int. Physiol. 37(1): 1–15.

39. Bjegović, P.
1963. **Contribution to the knowledge of competitory relations between *Ooencyrtus kuwanae* How. and *Anastatus disparis* R.** [in Serbo-Croatian, English summary]. Zast. Bilja 14: 543–552.

Laboratory experiments conducted at a constant 25 °C during the winter and spring of 1962–63 show the interaction between two egg parasites of the gypsy moth, *O. kuwanae* and *A. disparis*. As long as *A. disparis* larvae are in diapause, they cannot be hosts of *O. kuwanae*. However, *O. kuwanae* develops successfully as the parasite of larvae of *A. disparis* that have interrupted diapause. It can also parasitize their pupae. It is a comparatively frequent phenomenon (14 percent) that two *O. kuwanae* develop in a single gypsy

moth egg to the adult stage and that both specimens emerge from the chorion through the same opening. By examining the contents of a deserted chorion, it can be easily established whether *O. kuwanae* developed in it as a parasite or as a hyperparasite. If it developed as a hyperparasite, two types of excrement are found in the chorion as well as a respiratory funnel, and there are no remains of the gypsy moth embryo. These experiments show the possibility of utilizing activated larvae and pupae of *A. disparis* by *O. kuwanae* to maintain the parasite in its critical period.
**Eggs: 4**

40. Bjegović, P.
1964. **The influence of low temperatures on the last stage of *Anastatus disparis* Ruschka larvae** [in Serbo-Croation, English summary]. Zast. Bilja 15(77): 3–12.

Parasitized eggs of the gypsy moth were kept at 0°C. At this temperature, mature larvae of *Anastatus disparis* can remain latent for about 27 months. By delaying development of the parasite, it is possible to obtain adults of *A. disparis* for investigation in any season. Adults of the parasite can reproduce after being kept for 2 years in a cool place. Although deep-freezing at −34°C for a brief period can be tolerated by diapausing *A. disparis* larvae, the same temperature is lethal to gypsy moth larvae. At −34°C, part of the *A. disparis* population remains in diapause for nearly 2 years. However, a temperature of −45°C is lethal for the last stage of *A. disparis* larvae.
**Eggs: 4; Generation: 4**

41. Bjegović, P.
1964. **The sex ratio dependence of *Anastatus disparis* Ruschka according to the embryo stage of gypsy moth (*Lymantria dispar* L.)** [in Serbo-Croation, English summary]. Zast. Bilja 15: 569–576.

"Experiments and observations were carried out in order to establish the possibility [of] *Anastatus disparis* R. development in different embryo stage[s] of gypsy moth. The experiments pointed out that *A. disparis* can develop as a parasite in every embryo stage of gypsy moth. This property makes it possible to have two generations per year in Yugoslav mild-climate regions. The development of [the] parasite in fresh-laid eggs of gypsy moth is very successful. In this case the sexual index is very convenient and come[s] to 0.583. If the parasitism take[s] place in the late embryo stage of the gypsy moth, the development of *A. disparis* is less successful. Then the sexual index of the parasite is not so convenient and come[s] to 0.093."
**Eggs: 4; Sex ratio: 4**

42. Bogach, A. V., I. M. Zolotoverkhaya, and O. I. Kyrychenko.
1966. **Significance of light and temperature in the reproduction of *Porthetria dispar* L. and *Bombyx mori* L.** [in Ukrainian, Russian, and English summaries]. Dopov. Akad. Nauk. Ukr. Res. 6: 825–827.

"Experiments on the effect of light and temperature on the copulation, fecundation, and oviposition of eggs in *Porthetria dispar* and two varieties of *Bombyx mori* showed that light, as an independent factor and in conjunction with temperature, affects the yield and dynamics of flight of the moths, fecundation, and oviposition. The photoperiodic effect is most distinctly manifested [at] low temperatures. Twenty-four hours of lighting per day has an unfavorable effect on oviposition and the viability of the eggs. However, a study of the effects of light and temperature acting jointly on copulation, fecundation, and oviposition showed that the important factor is the temperature."
**Eggs: 12; Fecundity: 12**

43. Bolívar y Pieltain, C.
1923. **Studies on chalcids of the family *Eupelmidae*. III. Spanish species of *Anastatus*** [in Spanish]. Rev. Fitopatol. 1(4): 114–122.

44. Bowditch, F. C.
1922. **Notes on the gipsy moth in my unsprayed woods at East Marion, Mass. 1922.** Psyche J. Entomol. 29: 213–216.

From 1920 to 1922 the gypsy moth population increased in the pure oak and mixed oak-white pine stands under observation. Larvae were abundant by mid-June, and the "trees began to look thin." Green *Calosoma* were running on the trees but were not seen to attack as they had in previous years. By the end of June, in preparation for pupation, the larvae had bunched together on tree trunks or under branches. They were attacked by voracious *Calosoma* larvae which preferred the already torpid prepupae to the more active larvae. Various dipterans were observed around the larval bunches, but only a large grayish fly was observed

to larviposit. Wilt disease killed many larvae after they had bunched up. By the first week in July most of the larvae had spun a slight web and pupated in a loose mass or in groups of 10 to 12 curled up in leaves at the ends of branches. Most of the *Calosoma* had disappeared, although some of the larger preyed on pupae until the moths emerged on July 10. At the time of adult emergence, birds arrived, staying for the 2 to 3 days of the major emergence. Male moths were attacked more than females. Robins, kingbirds, vireos, chickadees, sparrows, blackbirds, and a variety of smaller birds were present. Gypsy moth females began to lay eggs almost immediately. All the clusters examined were parasitized by an insect imported from Japan whose imago emerges in the fall.

**Adults: 9; Eggs: 4; Larvae: 1, 3, 4, 7; Pupae: 3; Oak stands: 15**

45. Britton, W. E.
1935. **The gypsy moth.** Conn. Agric. Exp. Stn. Bull. 375: 625–647.

This bulletin deals with the distribution of the gypsy moth in the United States and abroad, with specific information on Connecticut, where the insect was first discovered in 1905. In 1913 it was found in 10 towns along the Rhode Island border, most likely having been dispersed there by wind. Windspread carried the moth further, so that by 1923, when the barrier zone was established, 100 Connecticut towns were infested. The bulletin also reviews favored food plants, life history and behavior of the moth, and its natural enemies. It includes defoliation statistics as well as information on the barrier zone, the Federal quarantine, and control measures.

**Generation: 2; Instars I–III: 1; All stands: 15**

46. Brown, G. S.
1967. **The gypsy moth, *Porthetria dispar* L., a threat to Ontario horticulture and forestry.** Proc. Entomol. Soc. Ont. 98: 12–15.

Birch and elm are the main hosts of the gypsy moth because they are the most prevalent trees in the area. "Maples are attacked to a lesser degree. Oak appears to be resistant, apparently owing to its delay in leafing out in the spring."

**Oak stands: 15; Non-oak stands: 15**

47. Brown, R. C., and R. A. Sheals.
1944. **The present outlook on the gypsy moth problem.** J. For. 42: 393–407.

This is a history of the gypsy moth in the United States with a detailed record of defoliation in New England. Also given are summaries of control measures and their effects.

**Review**

48. Bryantzev. B.
1928. **Some observations on the migration of the larvae of the gypsy moth from forests to fields and orchards in Kursk in 1927** [in Russian]. Zashch. Rast. (Leningrad) 5(3–4): 370–371.

49. Buckner, C. H.
1967. **Avian and mammalian predators of forest insects.** Entomophaga 12: 491–501.

Birds and mammals are homoiothermic, needing prodigious amounts of energy to maintain their body temperature and life processes. As a result, they have a high attack potential but one that is rarely satisfied by exclusive consumption of a specific food source. Thus, with vertebrate predators, more than with other parasites or predators, one must study the entire ecosystem of the pest because buffer species and alternative prey are of great potential importance. The functional and numerical responses of vertebrate predators to prey density are discussed in detail.

**Generation: 2, 9, 10**

50. Buckner, C. H.
1967. **The estimation of energy flow through the populations of birds.** Pages 163–178 *in* K. Petrusewicz, ed. Secondary productivity of terrestrial ecosystems. Working meeting of IBP Committee, 1966, Warsaw.

"The impact of birds on their food resources is obviously of importance in productivity relationships. Early authors tended to stress the regulatory nature of birds on their food supplies, especially birds as destroyers of noxious insects, but their opinions were more frequently colored by their emotions than by sound ecological data. Recent attempts to relate the regulatory action of birds on their food supply has produced conflicting results. Based upon regression types of analysis, several authors claim strong regulatory action, especially at low to moderate food densities, whereas others indicate only slight regulatory action or no regulation at all. Several authors stress the importance of birds in reducing residual populations of food reserves."

**Generation: 9**

51. Buckner, C. H.

1974. **Coactions of small mammals and larch sawflies.** Entomophaga Mem. H. S. 7: 71–81.

"The interrelationships of the larch sawfly and its small mammalian predators have been the subject of intensive investigation for many years. Small mammals usually destroy a large percentage of the cocoon population—at times over 90 percent. Mammal predation is a key factor in the population dynamics of the sawfly at low and moderate prey densities but not at high cocoon populations, although predation may at times act in a catastrophic manner to reduce the density of the pest insect. Two species of predators exhibited a weak numerical response to prey densities, but as prey numbers increased the relationship became less clear. Confounding factors tended to mask this relationship. All predator species exhibited marked functional responses to the density of the prey insect, a fact that greatly enhanced the regulatory value of the predators."

**Generation: 2; Pupae: 2, 10**

52. Burgess, A. F.

1897. **Notes on certain Coleoptera known to attack the gypsy moth.** Mass. State Bd. Agric. Annu. Rep. 44: 412–431.

The most important predaceous beetles known to attack the gypsy moth are in the genera *Calosoma* and *Harpalus,* family Carabidae. Prior to 1896 the following species were known to attack the gypsy moth in the field: *Ptinus brunneus* Duft. attacked eggs; *Calosoma calidum* (Fab.), *C. frigidum* Kirby, *C. scrutator* (Fab.), *Cicindela 6- guttata* Fab., *Harpalus caliginosus* Say., and *H. pennsylvanicus* (DeG.) attacked larvae; *Dermestes lardarius* L. and *Platynus limbatus* (Say.) attacked pupae. The number of gypsy moth larvae killed on the trees depends on the size and agility of the beetles; *Calosoma* is ranked, in descending order, *frigidum, calidum,* and *scrutator,* with *frigidum* also the most common. Its feeding activity increases with temperature, but it also feeds at night when gypsy moth larvae are active. Details on the rearing method and life history are given for *C. frigidum* and *C. calidum.* Despite their ability to eject a fine mist of pungent-smelling, caustic liquid, they are preyed on by insectivorous birds, toads, and skunks. *C. calidum* is parasitized by the dipteran *Pseudotraetocera calosomae* Coq.

**Eggs: 3; Larvae: 3; Pupae: 3**

53. Burgess, A. F.

1911. ***Calosoma sycophanta:* its life history, behavior, and successful colonization in New England.** U. S. Dep. Agric. Bull. 101. 94 p.

*Calosoma sycophanta* in its adult form is a beautiful green beetle, 1 inch long with long legs. It closely resembles the native *C. scrutator* Fab. and *C. wilcoxi* Lec. *C. scrutator* is more common in the central and southern United States, rarely occurring in the north. It is larger than *C. sycophanta* and can be distinguished by the purplish band on the green elytra and the shiny copper-colored margin on the thorax. *C. willcoxi* is also a southern species found occasionally in the north. It is smaller than *C. sycophanta* and has color markings similar to *C. scrutator.* This bulletin covers in detail methods of rearing, transporting, and colonizing the beetle, a report on colonies in Massachusetts, the economic importance of *C. sycophanta* in controlling the gypsy moth, and extensive morphological and ecological data.

**Larvae: 3; Pupae: 3**

54. Burgess, A. F.

1913. **The dispersion of the gipsy moth.** U. S. Dep. Agric. Bull. 119. 62 p.

Gypsy moth control work ceased in 1900, and when it was resumed in 1905 the infested area was found to be 6 times greater than it had been 5 years earlier. The automobile and electric trolley together with people and their parcels dispersed larvae and egg clusters. Automobile traffic between urban and rural areas was very heavy in June when the gypsy moth was most likely to be spread in its larval stage. Despite assertions to the contrary, the author did not believe that birds were responsible for dispersion into areas not reached by the automobile. Larvae carried by birds were usually injured in flight; eggs were rarely eaten by birds and when they were did not often pass through the alimentary tract unharmed. Local dispersion, however, could have been caused by egg clusters attached to nesting materials.

In 1909, E. D. Sanderson suggested that first-instar larvae were carried aloft by the wind by their aerostatic hairs, which disappear in later instars. Experiments to test larval dispersion by the wind, showed that larvae could not be induced to spin silk at temperatures below 65°F and that higher temperatures were preferable. Dispersion was more likely to be away from heavily infested areas where food was limited. The direction of the pre-

vailing wind on days in April and May when the temperature was greater than 70°F was correlated with the direction of spread of the gypsy moth. The wind was southwesterly 51 percent of the days when wind spread was possible, and expansion of the infested area was to the north, northwest, and northeast.
**Instars I–III: 1, 3, 12**

55. Burgess, A. F.
1914. **The gipsy moth and the brown-tail moth, with suggestions for their control.** U. S. Dep. Agric. Farmer's Bull. 564. 24 p.
A general statement covering the history of the gypsy moth in America, its life history, and favored food plants. Methods of control for both by laymen and in state control work are discussed.
**Generation: 1, 2; All stands: 15**

56. Burgess, A. F., and C. W. Collins.
1915. **The calosoma beetle (*Calosoma sycophanta*) in New England.** U. S. Dep. Agric. Bull. 251. 40 p.
Several species of *Calosoma* and *Carabus* (Coleoptera: Carabidae) were imported from Europe, but only *Calosoma sycophanta* became well established and abundant. The egg is 5.2 × 2.4 mm, elliptical and tapering at one end, and white with a faint yellow tinge. Eggs are deposited in the ground and hatch in 3 to 10 days, depending on temperature. The larva is nearly white upon hatching but remains in the egg cavity until it becomes jet black, then making its way to the soil surface to search for food. It attacks lepidopterous larvae and pupae without regard to size, approaching larvae from the lateral or ventral side and penetrating between segments of hairy larvae. Pupae are also attacked between segments, which leaves an irregular hole that can be easily distinguished from parasite exit holes. The *Calosoma* larvae feed day and night; can climb rough-barked trees; are more active with higher temperatures; are not affected by wilt; and can kill an average of 41 full-grown gypsy moth larvae. They are found in the field roughly from the end of June through August. They molt twice, attaining a full-grown size of 25.8 × 5.7 mm. A pupal chamber is constructed in the soil above the frost line. The prepupal stage is 10 days and the pupal stage 13 days, after which the adult emerges but stays in the pupal cavity over winter until it surfaces June 1. Adult beetles live 2 to 4 or more years. Older adults also surface June 1, having been in an underground cavity since mid-July of the previous year. Adults feed in trees, seizing larvae in the middle of the back and cutting through the body wall. They feed on liquids and fatty material of the prey, injuring more than they devour. *Calosoma* beetles can fly freely to migrate in the spring, can swim, and can live submerged in water for at least 4 days. They copulate a few days after emerging and feeding. The female must mate several times in the season; otherwise, she will lay many infertile eggs. Older beetles lay more eggs, an average of 100 per season. *C. sycophanta* is preyed upon by birds (including crows and hairy woodpeckers) and by raccoons, foxes, and skunks, the last of which will upturn soil in the search. The adult is attacked by the tachinid *Viviania georgiae*, and adults and larvae are attacked in captivity by the mite *Tyroglyphus armipes*. Rearing methods are also described in this bulletin. It is concluded that the life cycle of *C. sycophanta* makes it a predator well suited to the gypsy moth.
**Larvae: 3; Pupae: 3**

57. Burgess, A. F.
1915. **Parasite work.** The State Forester. Publ. Doc. 73: 84–88, Massachusetts.
Examination of egg clusters from northern Massachusetts and New Hampshire showed that parasitism by *Anastatus bifasciatus* was often 25 percent and sometimes as high as 43 percent.
**Eggs: 4**

58. Burgess, A. F.
1915. **Report on the gipsy moth work in New England.** U. S. Dep. Agric. Bull. 204. 32 p.
Report on field and experimental work pertaining to the gypsy moth done by the U. S. Department of Agriculture Bureau of Entomology in Boston under the direction of the author.
**Generation: 1, 2**

59. Burgess, A. F.
1916. **Suppression of the gipsy and brown-tailed moths and its value to states not infested.** U. S. Dep. Agric., Yearb. Agric., 1916.
The history of the gypsy moth and brown-tail moth in the United States is given, and a distinction is drawn between the nuisance value of the former and the problem of poisonous larval hairs

of the latter. Conclusions from earlier experimental work of the author and his colleagues are given. The author emphasizes the cost of control operations to local governments, pointing out that other areas of the country are benefiting as a result.
**Generation: 1; All stands: 15**

60. Burgess, A. F.
1917. **The gipsy moth and the brown-tail moth and their control.** U. S. Dep. Agric. Farmer's Bull. 845. 28 p.
This is a public information bulletin, giving the life history and the natural and artificial controls of the gypsy and browntail moths.
**Larvae: 1; All stands: 15**

61. Burgess, A. F., and C. W. Collins.
1917. **The genus *Calosoma*: including studies of seasonal histories, habits, and economic importance of American species north of Mexico and of several introduced species.** U. S. Dep. Agric. Bull. 417. 124 p.
Included in this paper are keys to the species of *Calosoma* larvae and adults and their original description as well as the distribution, ecology, and references for each of the species considered. *Calosoma* and *Carabus* were originally grouped together but were separated into two genera in 1801. The various *Calosoma* species have similar habits and life histories. Also covered are natural enemies of *Calosoma* and methods for transporting and rearing them.
**Larvae: 3; Pupae: 3**

62. Burgess, A. F.
1924. **The value of natural enemies of injurious insects.** Annu. Rep. Entomol. Soc. Ont. 54: 30–36.
Parasites and predators are necessary to control the population levels of injurious insects, and natural enemies in the native area of the pest species should be utilized. Population fluctuations in the native area should be studied. A table is given listing the numbers of imported gypsy moth parasites released in New England.
**Generation: 4**

63. Burgess, A. F.
1926. **The present status of the control of the gipsy moth and the brown-tail moth by means of parasites.** J. Econ. Entomol. 19: 289–294.
The results of the introduction of the parasites of the gypsy moth, *Porthetria dispar,* and brown-tail moth, *Euproctis chrysorrhoea* are described. Up to the time of publication, 60 species of parasites and predaceous beetles had been imported from Europe and Japan, 16 of which became established in New England. The species that were well established and abundant by 1914 were *Calosoma sycophanta* L., a predaceous beetle attacking larvae and pupae; *Compsilura concinnata* Meig., a tachinid parasite of larvae; and *Anastatus bifasciatus* Fonsc., an encyrtid egg parasite. In 1916, *Schedius kuvanae* How., another encyrtid egg parasite, *Blepharipa scutellata* R. D., a tachinid attacking larvae, and *Apanteles melanoscelus,* a braconid attacking larvae, were found in considerable numbers. Beginning in 1915, the area of defoliation by the gypsy moth began to decrease gradually, owing to a reduction of favored food, nonhatch of egg clusters, and wilt disease as well as to the increase in parasitism. The average parasitism by all species combined gradually increased and reached a maximum in 1923.
**Eggs: 4; Larvae: 3, 4; Pupae: 3**

64. Burgess, A. F., and S. S. Crossman.
1929. **Imported insect enemies of the gipsy moth and the brown-tail moth.** U. S. Dep. Agric., Tech. Bull. 86. 147 p.
Life histories of the gypsy moth and the brown-tail moth are given. Also included are their introduction and spread in the United States and the efforts of the Bureau of Entomology, beginning in 1905 and again in 1922, to introduce natural enemies from Europe and Japan. Detailed information is given about the 1922 project. Over 93 million parasites and predators of the two pests were liberated from 47 species, 15 of which were positively established and 9 or 10 of which became important in New England. The report contains detailed information on imported parasites and invertebrate predators encountered in investigations; earlier work is covered by Howard and Fiske (1911).
**Eggs: 4; Instars I–III: 4; Larvae: 3, 4; Pupae: 3, 4.**

65. Burgess, A. F.
1944. **The gypsy moth and brown-tail moth: a history of the work for prevention of spread and extermination of these insects in North**

**America.** U. S. Dep. Agric., Agric. Res. Admin., Bur. Entomol. Plant Quar., Div. of Gypsy Moth and Brown-Tail Moth Control. Greenfield Mass. 334 p.

This report covers work on the gypsy moth from 1890 and on the brown-tail moth from 1897 in the United States. It deals with the efforts of each of the involved states and of the Federal Government, synthesizing the literature published on the subject over the years.

**Review**

66. Burks, B. D.

1960. **A revision of the genus *Brachymeria* Westwood in American north of Mexico (Hymenoptera: Chalcididae).** Trans. Am. Entomol. Soc. (Philadelphia) 86: 225–273.

All species of *Brachymeria* look alike, but they differ widely in their habits. *Brachymeria intermedia* (Nees) = *Chalcis intermedia* Nees = *Chalcis flavipes.* Type locality is in Sickershausen, Germany, and it is distributed in Europe, the Mediterranean region, Asia Minor, the Middle East, Iraq, Iran, Turkeman, the USSR, and perhaps Massachusetts. It was introduced to New England between 1905 and 1933 but is thought not to have become established, although in 1942 a female was reared from a native *Cacoecia* pupa. It is a primary parasite of 10 families of Lepidoptera pupae and will also parasitize muscoid puparia.

**Pupae: 4**

67. Buttner, H.

1961. **The influence of fertilizers on the mortality and development of insect pests of forests exerted through their food plants** [in German, English summary]. Schr. Reihe Landesforstverwalt Baden-Württemberg 11(69).

Laboratory experiments on the effect of fertilizers on the mortality of lepidopterous larvae feeding on trees are reported. There is an increase in mortality of "pre-imaginal stages of *Lymantria monacha* (L.), *L. dispar* (L.), and *Pristiphora abietina* on young spruce trees, the results varying with the proportions of the elements in the fertilizers." The effect of the fertilizers on the development of the survivors could not be determined accurately owing to interfering factors. "In field tests in an area long infested with *P. abietina,* the use of calcium ammonium nitrate . . . resulted in 50 percent mortality of the larvae. The way in which mortality is brought about is not known. A correlation was demonstrated between insect mortality and the nitrogen content of their food. Amino acids may be of importance."

**Larvae: 13; Non-oak stands: 23**

68. Campbell, R. W.

1959. **The development of environmental resistance tables for gypsy moth, *Porthetria dispar* (L.).** M. S. thesis., Univ. Mich., Ann Arbor.

This evaluation of environmental resistance to the gypsy moth is based on observations of a 13.6-acre infested woodlot in Glenville, N. Y. Behavior of larger larvae and pupae differed in each of four environmental subsites differentiated by the depth of the water table. Efficacy of biotic control agents also varied with the site. For example, in a moderately moist site—the "transition site"—large larvae descended to the leaf litter during the day and exposed themselves to both small mammal predation and to a habitat favorable to the virus disease. As a consequence, the transition site was the only one of the four not susceptible to gypsy moth outbreak. Dispersal, exposure, drowning, *Calosoma* predation, small mammals, tachinid parasites, and disease all played a primary role in the environmental resistance complex. Tables are given showing the effects of these factors on survival in each of the sites.

**Adults: 1; All stands: 15; Eggs: 4, 12; Generation: 1; Instars I–III: 1, 12; Instars IV–VI: 1, 12; Larvae: 3, 4, 7, 9, 10; Pupae: 1, 4, 10**

69. Campbell, R. W.

1961. **Population dynamics of the gypsy moth.** Ph.D. thesis, Univ. Mich., Ann Arbor.

This comprehensive study of the effects of natural factors on gypsy moth populations under various field conditions drew the following conclusions: (1) Sparse populations are probably controlled largely by vertebrates, especially small mammals. (2) Intermediate populations are sometimes damped in their tendency to increase by birds and tachinid parasites. This damping influence may occasionally prolong gypsy moth outbreaks. (3) Dense populations collapse primarily because of the combined effects of disease, desiccation, and ichneumonids. (4) Dry weather may produce conditions on mesophytic sites that will cause an otherwise sparse larval population to stay in the trees, and this in turn may trigger an outbreak. Additional information is given on the parasites,

predators, scavengers, disease, and mortality of the gypsy moth. The thesis lists 57 references.

**Generation 1, 2, 4, 9; Instars** I–III: **1, 9; Instars** IV–VI: **1, 3, 4, 6, 7, 9, 10; Prepupae: 3, 4, 6; Pupae: 3, 4, 6, 10; Sex ratio: 4, 6; Fecundity: 12; All stands: 15, 20**

70. Campbell, R. W.
1963. **The role of disease and desiccation in the population dynamics of the gypsy moth *Porthetria dispar* (L.) (Lepidoptera: Lymantriidae).** Can. Entomol. 95: 426–434.

"The population dynamics of the gypsy moth, *Porthetria dispar* (L.), are being studied on 10 sites in the Town of Glenville, N. Y. This paper discusses the role of disease and a condition here termed desiccation in the dynamics of these populations during a four-year period, 1958–1961 inclusive. The term desiccation refers to dead prepupae that appeared shriveled, were stiff to the touch, and had a solid mass of food in their gut. The incidence of desiccation among prepupae was closely related to the number of eggs per egg mass produced at the end of the generation (a measure of relative insect density). Disease incidence among larval gypsy moth populations was directly related to insect density. Disease incidence was also related to site conditions, with higher mortality occurring in wet sites. When larval populations reached high densities, they always declined from the dense level within a few generations. These declines ranged from a sudden drastic reduction to a much more gradual decline. The former was preceded by virtual food exhaustion, while the latter was not usually preceded by exhaustion of the food supply. Disease and desiccation were primary factors in producing the sudden type of population reduction noted above. Pathogens may also play an important part in the more gradual type of decline, but this point remains to be clarified.

**Eggs: 2; Instars** IV–VI: **6, 12; Prepupae: 6**

71. Campbell, R. W.
1963. **Some factors that distort the sex ratio of the gypsy moth *Porthetria dispar* (L.) (Lepidoptera: Lymantriidae).** Can. Entomol. 95: 465–474.

"During a study on the population dynamics of the gypsy moth, *Porthetria dispar* (L.), conducted in the Town of Glenville, N. Y. some factors were found to affect the sexes differentially. The importance of this differential mortality is indicated by the fact that 78 percent of the variation in the logarithm of an index of population trend (the ratio of population density from year to year) was associated with the logarithm of adult sex ratio. Disease and desiccation during instars IV to VI and among prepupae were strongly selective against the female insects. This differential mortality caused a change in the pupal sex ratio from about 70 percent females where no disease occurred to less than 25 percent female pupae following on epizootic. Ichneumonids, on the other hand, usually killed more male pupae than females, except when host size was reduced by excessive larval density and competition. The net result from this series of factors that distort the sex ratio has been to produce adult sex ratios varying from more than 80 percent female moths to only 2 percent females. In this host species, as in most other animals, it seems that the population consequences of a mortality factor that kills the host sexes in different proportions should be evaluated in terms of the more critical (female) sex destroyed."

**Instars** IV–VI: **6; Prepupae: 6; Pupae: 4, 6,; Sex ratio: 2, 4, 6**

72. Campbell, R. W.
1963. **Some ichneumonid-sarcophagid interactions in the gypsy moth *Porthetria dispar* (L.) (Lepidoptera: Lymantriidae).** Can. Entomol. 95: 337–345.

"Four ichneumonid species, *Itoplectis conquisitor* (Say), *Pimpla pedalis* Cress., *Theronia atalantae* (Poda), and *Theronia hilaris* (Say), were seen attacking the gypsy moth, *Porthetria dispar* (L.), in the Town of Glenville, Schenectady County, N. Y. These species stung and killed many more host pupae than they successfully parasitized (success here being measured by the development of an ichneumonid offspring within the host). The ratio between the total number of hosts stung by ichneumonids and the number of ichneumonid offspring emerging was different for each of the three primary ichneumonids studied, ranging from 4 to 1 for *T. atalantae* to more than 200 to 1 for *I. conquisitor*. The sarcophagids associated with the gypsy moth, although apparently parasitic, are largely scavengers. Their attacks almost always follow those of ichneumonids. Since the sting of an ichneumonid kills the host but is not always discernible, the number of pupae containing

sarcophagid larvae has been used to indicate the true effects of ichneumonids on the host population."

In one study, 925 pupae and prepupae that were known to have been stung by ichneumonids were subsequently examined. Only 18 of these produced adult gypsy moths, and only 8 produced ichneumonid offspring. The 84 prepupae known to have been stung by ichneumonids failed to produce a single ichneumonid. Of an additional 4522 dead prepupae examined in the field, not one contained an ichneumonid offspring.

**Prepupae: 4; Pupae: 4**

73. Campbell, R. W.
1966. **Gypsy moth egg-mass density and subsequent defoliation.** U.S. Dept. Agric. For. Serv. Res. Note NE-44. 6 p.

"Percentage defoliation of oak by the gypsy moth . . . [was found to be] directly related to egg-mass density at the start of each year, and inversely related to the trend in egg-mass density from the preceding year . . . These relationships were not close enough to provide a useful predictive equation, . . . [but] clear-cut expectations of given defoliation levels can be calculated when broad categories are used."

**Oak stands: 15, 19; Eggs: 2**

74. Campbell, R. W.
1967. **Studies on the sex ratio of the gypsy moth.** For. Sci. 13: 19–22.

"The sex ratio among gypsy moth (*Porthetria dispar* (L.)) embryos and newly hatched larvae approximated 50:50. By the time the insects reached instar II, however, the sex ratio had changed so that there were more female than male insects in the population. The sex ratio among both instar III and instar IV larvae continued to be distorted in favor of the females and averaged about 66:34 at the start of instar IV. These findings complete the quantitative basis required for the explicit analysis of the female component of gypsy moth populations." Changes in the adult sex ratio were caused primarily by certain types of mortality, as shown in earlier studies. These agents included disease in instars IV to VI and larval and pupal parasitism by ichneumonids.

**Instars IV–VI: 6; Pupae: 4; Sex ratio: 4, 6**

75. Campbell, R. W.
1967. **Measuring age-specific mortality factors of the gypsy moth.** Proc. North Cent. Branch Entomol. Soc. Am. 22: 53–56.

Methods are discussed for "estimating each of three different sorts of mortality factors: first, mortality caused by ichneumonids among dense populations of pupae; second, predation by vertebrates among sparse populations of instar IV through VI larvae and pupae; and third, components of disease among dense populations of the large larvae."

**Instars: IV–VI: 1, 5, 6, 7, 10; Pupae: 4, 10**

76. Campbell, R. W.
1967. **The analysis of numerical change in gypsy moth populations.** For. Sci. Monogr. 15. 33 p.

"A study of gypsy moth, *Porthetria dispar* (L.), population dynamics was carried out over a 7-year period in several areas in northeastern New York. The data were summarized in life tables, stratified by density and sex, and then analyzed by mathematical models. Variation in the survival rates of the instar IV to VI female larvae and the female pupae was the greatest source of variation in density among dense populations. Variation in the survival rates of both instar I to III and IV to VI female larvae was most important among sparse populations. Disease was the primary determinant of variation in the survival rate of dense populations of instar IV to VI larvae, while agents other than disease or parasites were most important at this stage among sparse populations. The survival rate of dense populations of the female pupae varied primarily in response to parasites and disease. Variation in the survival rate of the instar I to III larvae was probably primarily a function of variation in the dispersion rate of the newly hatched larvae. A generation model was developed that describes density at the start of a second generation as a function of the environmental variables associated with the above mortality-causing factors. It was tested against an independent body of data with some success."

**Instar IV–VI: 2, 6; Larvae: 1, 3, 4; Pupae: 2, 4, 6**

77. Campbell, R. W.
1969. **Studies on gypsy moth population dynamics.** Pages 29–34 *in* Forest Insect Population Dynamics. U.S. Dept. Agric. For. Serv. Res. Pap. NE-125.

The survival rate of later instar female larvae and pupae represented the greatest source of density variation in dense populations. Variation in survival rate of all larval stages (female) was most important in sparse populations. Disease was the primary cause of variation in survival rate in dense populations of instar IV to VI female larvae, while agents other than disease or parasites were most important in sparse populations. Female pupal survival rate varied primarily in response to ichneumonids and disease. Instars I to III probably varied in survival rate as a function of variation in the dispersion rate of the newly hatched larvae. "An index of disease incidence among instar IV to VI larvae was a curvilenear function of insect density, a linear function of precipitation during June, a linear function of the percent of swamp white oak in the overstory, and a function of an interaction between density and precipitation."
**Instars IV–VI: 6; Pupae: 6**

78. Campbell, R. W., and J. D. Podgwaite.
1971. **The disease complex of the gypsy moth. I. Major components.** J. Invertebr. Pathol. 18: 101–107.

"A study was undertaken to elucidate the impact of the various components of disease on natural populations of the gypsy moth, *Porthetria dispar.* Diseased larvae from both sparse and dense populations were examined and categorized on the basis of etiologic and nonetiologic mortality factors. Results indicated a significantly higher incidence of parasite involvement—but virtual nonexistence of polyhedral viruses—in the relatively stable sparse populations. Nuclear polyhedrosis probably represented the primary mortality factor in the dense populations. Many insects examined from both population types revealed no infectious agent or overt cause of disease, a fact that may indicate a major regulatory role of noninfectious disease in natural populations. Variation in the disease complex within the populations that have been studied indicates that minor causes of disease in one may well predominate in others. Thus, to fully understand this complex, it must be studied across a number of years within a series of populations from different geographical areas."
**Larvae: 5, 6, 7**

79. Campbell, R. W.
1971. **Developing a pest population management system.** Pages 9–20 *in* Proc. Tall Timbers Conf. Ecol. Anim. Control Habitat Manage.

Development of a program designed to achieve reasonable control of the gypsy moth without degrading the environment is discussed. It has four interlocking parts—prediction, understanding, control, and integration.
**Generation: 2**

80. Campbell, R. W. , and H. T. Valentine.
1972. **Tree condition and mortality following defoliation by the gypsy moth.** U.S. Dep. Agric. For. Serv. Res. Pap. NE–236. 331 p.

"The objective of [this] work is to present a basis from which increasingly accurate forecasting schemes can be developed for predicting both tree condition and mortality subsequent to defoliation. This basis, which is derived from a review of certain historical records, consists of a series of 323 tables giving both annual and cumulative tree mortality rates, as well as the subsequent condition classes of the surviving trees, for particular tree species or species groups, and according to the history of defoliation. These tables were prepared by sorting raw data from permanent plots."

The records used were compiled between 1911 and 1931 from 264 circular plots (0.18-acre) along the eastern seaboard of New England, from Wareham, Mass., to Kennebunk, Me. Annual records were maintained through 1922 on 121 of the original plots. Average mortality at the end of this period was 58 percent in white oak, 55 percent in gray birch, 46 percent in both black and scarlet oak, 27 percent in red oak, 26 percent in white pine, and 25 percent in red maple. Within any given species, mortality rates tended to be highest among suppressed trees and lowest among dominants and also highest among trees classified in poor condition prior to defoliation. Species alteration because of gypsy moth activity was not documented directly, but it can be inferred from the records that the decline of pioneer gray birch stands was accelerated, that the ratio of white to red oak was reduced, and that the white pine component of mixed stands was increased.
**Oak stands: 15, 19, 20, 24, 25, 26, 27**

81. Campbell, R. W.
1973. **Numerical behavior of a gypsy moth population system.** For. Sci. 19:162–167.

"The numerical behavior of a gypsy moth population system observed in eastern New England between 1911 and 1931 is described. Rates of change in egg mass density from year (n) to (n + 1) were related to rates of change in density from years (n − 1) to (n) and to an index of the density level of the overall population system, termed zone density. When zone density was high, individual populations tended to increase to and maintain high density levels. When zone density was low, individual populations tended to achieve and maintain low densities. Numerically unstable populations between years (n − 1) to (n) tended to remain numerically unstable from years (n) to (n + 1)."

**Generation: 1, 2**

82. Campbell, R. W.
1973. **Forecasting gypsy moth egg-mass density.** U.S. Dep. Agric. For. Serv. Res. Pap. NE–268. 19 p.

"Several multiple-regression models for gypsy moth egg-mass density were developed from data accumulated in eastern New England between 1911 and 1931. Analysis of these models indicates that: (1) the gypsy moth population system was relatively stable in either the OUTBREAK phase or the INNOCUOUS one; (2) several naturally occurring processes that could terminate the OUTBREAK phase are represented by the models, but they do not indicate mechanisms sufficient to change the system for the INNOCUOUS phase to the OUTBREAK one. Some of the implications arising from the above conclusions are discussed." Results from the data also support the following conclusions: (1) Heavy precipitation in June of the year (n + 1), if sufficiently widespread, may indicate the abrupt collapse of the OUTBREAK phase; and (2) mechanisms similar to those described by Wellington (1965) for the western tent caterpillar and by Morris (1969) for the webworm may also operate in the dynamics of gypsy moth populations.

**Eggs: 2; Generation: 2, 12**

83. Campbell, R. W.
1974. **Relationships between overstory composition and gypsy moth egg-mass density.** U.S. Dept. Agric. For. Serv. Res. Note NE–191. 6 p.

This study provides evidence that the favored food theory has relatively little merit, at least with respect to relationships between overstory composition and subsequent gypsy moth population density. There was virtually no difference between the stable-state distribution of gypsy moth egg-mass densities in favored food stands and that in poor food stands when zone densities (egg-masses per acre) were low, and surprisingly little when they were high. "About 17 percent of the favored food stands could be expected to support more than 5,000 egg masses per acre when zone density was high, compared with only about 10 percent of the poor food stands. An almost identical proportion of the stands in each cover type could be expected to support fewer than 500 egg masses per acre at high zone densities."

**Eggs: 12**

84. Campbell, R. W.
1974. **Relation between overstory composition and subsequent defoliation by the gypsy moth.** J. For. 72.

"The percentage of favored food in the overstory was closely related to the subsequent level of defoliation by the gypsy moth. Thus the silvicultural recommendations that are based on the 'favored food' theory may be valid with respect to abating the damage done by this insect to the forest." The percentage of favored food in the overstory was not closely related to gypsy moth egg-mass density.

**Oak stands: 15, 20, 21**

85. Campbell, R. W., and J. P. Standaert.
1974. **Forecasting defoliation by the gypsy moth in oak stands.** U.S. Dept. Agric. For. Serv. Res. Note NE–193. 7 p.

"A multiple-regression model is presented that reflects statistically significant correlations between defoliation by the gypsy moth, the dependent variable, and a series of biotic and physical independent variables. Both possible uses and [possible] shortcomings of this model are discussed."

**Oak stands: 15**

86. Campbell, R. W.
1974. **The gypsy moth and its natural enemies.** U. S. Dept. Agric., Agric. Inf. Bull. 381. 27 p.

"Patterns of gypsy moth behavior are described, especially those related to population density. Natural mortality-causing factors that operate

against this insect are also described. Several agents kill subadult male and female gypsy moths at different rates. Major determinants of year-to-year changes in gypsy moth numbers are described."
**Review**

87. Campbell, R. W., D. L. Hubbard, and R. J. Sloan.
1975. **Patterns of gypsy moth occurrence within a sparse and numerically stable population.** Environ. Entomol. 4: 535–542.

"Patterns of subadult gypsy moth, *Porthetria dispar* (L.), occurrence within a sparse, numerically stable population that was studied in 1965 were modeled as functions of insect stage and certain components of environmental structure. Our results imply that (a) once newly hatched larvae find suitable foliage, they tend to stay on or near it until after they have molted into instar III; (b) these insects begin to wander sometime before reaching instar IV, and continue to do so until suitable daytime resting locations are found. These locations are usually in the litter at the tree base, but the insects will aggregate under bark flaps on dead limbs or on the dead boles of trees in clumps in preference to the litter if these are available; (c) most of the insects pupate in the locations used earlier for resting sites, but some eventually pupate in objects that may be many feet away from the closest living host tree; and (d) bark flaps may have provided less hazardous resting sites for the growing larvae and pupae than other potential resting locations within the environment."

The percentage of insects more than 6 feet above the forest floor was about 45 percent as the insects began to molt into instar V, increasing to 65 percent at the pupal stage, and stabilizing at 65 percent. About 45 percent of the insects were found between the litter and 6 feet above the forest floor as they began to molt into instar V. This declined to 10 percent as the insects began to pupate, then rose to about 25 percent as the last larvae pupated. About 10 percent were found in litter as they began to molt into instar V and 30 percent as the insects began to pupate. The percentage then declined steadily as pupation progressed.
**Instars** I–III: **1; Instars** IV–VI: **1; Larvae: 1; Pupae: 1**

88. Campbell, R. W., D. L. Hubbard, and R. J. Sloan.
1975. **Location of gypsy moth pupae and subsequent pupal survival in sparse, stable populations.** Environ. Entomol. 4: 597–600.

"About 90 percent of the gypsy moth, *Porthetria dispar* (L.), pupae found in a series of sparse stable populations studied between 1965 and 1968 were either beneath bark flaps or in the litter. Male larvae were more likely to pupate in bark flaps than females. Pupal survival was usually higher among pupae beneath bark flaps than among those in the litter, and bark flaps provided virtually the only pupation locations in the whole environment, within the highest density stratum studied, where female pupae had a reasonable survival probability. Adult gypsy moth production in these populations could be accurately estimated from knowledge of pupal density and sex ratio, and the number of bark flaps per 0.01-acre. Bark flap removal is suggested as a potentially useful technique for preventing outbreaks."
**Adults: 2; Pupae: 1, 12**

89. Campbell, R. W.
1975. **The bimodality of gypsy moth, *Porthetria dispar* (L.) (Lepidoptera: Lymantriidae) populations (Abstract).** J. N. Y. Entomol. Soc. 83:287–288.

Populations of the gypsy moth in North America tend to have two numerical modes—innocous and outbreak. A population may remain in the innocuous mode for many years, but an outbreak within a general area may last for as long as a decade. Changes from the innocuous mode to the outbreak mode and vice versa usually occur within 2 or 3 years.
**Generation: 2**

90. Campbell, R. W., M. G. Miller, E. J. Duda, C. E. Biazak, and R. J. Sloan.
1976. **Man's activities and subsequent gypsy moth egg-mass density along the forest edge.** Environ. Entomol. 5:273–276.

"When gypsy moth, *Porthetria dispar* (L.), egg-mass density was low (less than 50 egg masses/acre), density was 10 times higher along the forest edge than within the forest. Man-made objects (MMOs) left along the forest edge in suburban areas contained ca. 1/2 of the egg masses found at low densities. MMOs that were rough, or dry, or protected from light contained

more egg masses than those that were smooth, or frequently moist, or exposed to light. Rough, dry MMOs that were protected from light contained the most egg masses. Apparently, these latter MMOs function as "bark flap" equivalents by providing a degree of protection for the growing larvae and pupae. It is postulated that sparse gypsy moth populations may tend to increase numerically from innocuous levels in situations where abundant larval resting and pupation locations other than the litter are available for the growing insects. Thus, littering the forest edge with MMOs could be a "triggering mechanism" for subsequent gypsy moth outbreaks."
**Eggs: 2,12; Generation: 2,12**

91. Campbell, R. W., and R. J. Sloan.
1976. **Influence of behavioral evolution on gypsy moth pupal survival in sparse populations.** Environ. Entomol. 5:1211–1217.
"Vertebrate predators killed about 70 percent of the gypsy moth, *Lymantria dispar* (L.), pupae in a series of sparse, numerically stable populations studied in New England between 1965 and 1968; and white-footed mice, *Peromyscus leucopus* Raf., were the most important predators. Pupae in the litter were more likely to be preyed upon than those in other locations, and female pupae were more likely than males to be killed by vertebrates. All other agents (primarily parasites) killed about 15 percent of the pupae. It is postulated that the growing insects exhibit behavior that enables them to evade natural enemies in Europe, by resting and pupating in the litter at the bases of their host trees. In North America, however, this behavioral trait often assures not only high gypsy moth mortality but also the destruction of many of the parasites that may have caused this trait to evolve. It is also postulated that a new behavioral adaptation may be evolving by this pest in response to new conditions in North America. Certain management implications from the above findings and postulates are described, and further research studies are recommended."
**Larvae: 1,4,9,12; Pupae: 1,4,10,12**

92. Campbell, R. W.
1976. **Comparative analysis of numerically stable and violently fluctuating gypsy moth populations.** Environ. Entomol. 5:1218–1224.
"Sparse gypsy moth, *Lymantria dispar* L., populations studied in the vicinity of Glenville, N. Y. between 1958 and 1964 tended to increase rapidly to outbreak levels. Conversely, equally sparse populations studied in the vicinity of Eastford, Conn. between 1965 and 1971 tended to remain sparse. Major mechanisms determining numerical differences between the two areas acted primarily during three age-intervals. First, the survival rate among instars I to III was higher in Glenville than in Eastford, although this difference decreased as density increased. These results were interpreted as a consequence primarily of airborne dispersal processes that occur largely during instar I. Second, the survival rate among instars IV to VI was higher in Glenville than in Eastford, and this difference increased as density increased. Although predation processes were probably responsible for most of the instar IV to VI mortality among the sparse populations in both areas, these results suggest that predation during this state was effective in maintaining sparse populations at innocuous levels only in Eastford. Third, pupae were more likely to survive in Glenville than in Eastford, and this difference was relatively constant across the entire density range that was common to the two areas. Since vertebrate predators, especially *Peromyscus leuopus*, were known to have killed most of the pupae in the Eastford populations, these results imply that these predators played a major role in maintaining the Eastford populations at innocuous levels."
**Generation: 1,2; Instars I–III:2; Instars IV–VI: 2,9,10; Pupae: 2,10**

93. Campbell, R. W., and R. J. Sloan.
1977. **Natural regulation of innocuous gypsy moth populations.** Environ. Entomol. 6:315–322.
"Preliminary studies on the determinants of numerical stability among a series of sparse gypsy moth, *Lymantria dispar* (L.), populations studied between 1965 and 1970 led to the hypothesis that year-to-year numerical stability among these populations was determined largely by a combination of predaceous birds, which tended to concentrate on instar IV to VI larvae and small mammals, especially *Peromyscus leucopus*, which tended to concentrate on the pupae. Test results in 1971 both supported the above hypothesis and emphasized the importance of selective predation on the female pupae by mammals in maintaining these sparse populations at innocuous levels. These same results also indicated that vertebrate

predators were consuming about one half of the parasitized instar IV to VI larvae and most of the parasitized pupae in the sites studied. Thus, the percentage of the gypsy moth population that *contains* parasites may often be much higher than the percentage that is actually *killed* by these same parasites. These results suggest not only that the activities of vertebrate predators may have been critically important in maintaining these sparse gypsy moth populations at innocuous levels, but also that the role of parasites in the dynamics of such populations in North America may be considerably more constrained by the activities of these predators than has previously been reported. Conversely, parasites may play their most important role within outbreak foci, since these foci are characterized in part by sparse gypsy moth populations that exhibit exceptionally low rates of vertebrate predation."

**Instars** IV–VI: **4,9,10,12; Pupae: 4,10,12; Sex ratio: 10**

94. Campbell, R. W., and R. J. Sloan.
1977. **Release of gypsy moth populations from innocuous levels.** Environ. Entomol. 6:323–330.

"Prior studies led to the premise that gypsy moth, *Lymantria dispar* (L.), populations tend to increase numerically from innocuous levels in environments where abundant, sheltered resting and pupation locations reduce the probability that the growing insects will be eaten by vertebrates. Although such locations may be found anywhere within the environment, and either may occur naturally or be introduced by man, they are usually above the forest floor, close to or part of a suitable host tree, and dark, dry, and rough. Test results described herein both supported this premise and led to the conclusion that environmental conditions that tend to produce or represent abundant sheltered locations for this pest also tend to produce or represent potential outbreak foci. Such environmental conditions include dry, rocky ridges, excessively drained sands, remnant "wolf-trees," and ice storms. Other environmental conditions that may contribute to the release of gypsy moth populations from innocuous levels include changes in habitat or food sources of predators, tree age, nutrient and moisture deficiencies, air pollution, land abuse, and climate. Qualitative differences between individual insects may also contribute to population release from innocuous levels."

**Generation: 2,12; Instars: IV–VI 9,10,12; Pupae: 10,12**

95. Campbell, R. W., and R. J. Sloan.
1977. **Forest stand responses to defoliation by the gypsy moth.** For. Sci. Monogr. 19.

"Records accumulated between 1911 and 1931 from a series of plots in eastern New England were analyzed to determine some of the changes in the forest that followed heavy and repeated defoliation by the gypsy moth, *Lymantria dispar* (L.) Oak trees required about 10 years to recover totally from a single heavy defoliation. Dominant trees were degraded less than subdominants and were less likely to die. Trees rated in poor condition were more likely to die after defoliation than those rated good. Tree species not favored as food by the insects were more likely to die after heavy defoliation than oak trees. Red maple, *Acer rubrum* (L.), was more likely to be killed by one heavy defoliation than white pine, *Pinus strobus* (L.). When defoliation, overall, was low, nearly all of it occurred on favored-food trees, but the insects became less selective as overall defoliation increased. Heavy and repeated defoliation resulted in more and more one-storied stands. For two reasons, heavy defoliation and subsequent tree mortality tended to reduce the susceptibility of the residual stand to further defoliation. First, differential loss rates *among* favored-and nonfavored-food species tended to alter forest composition toward less susceptible types. Second, certain trees *within* any given tree species were consistently defoliated more heavily than others. These trees were also more likely to die."

**Generation: 2; Oak stands: 15,16,19,20,21, 22,24,25,26,27,28; All stands: 15,16,19,20,21,22, 24,25,26,27,28**

96. Capinera, J. L., and P. Barbosa.
1976. **Dispersal of first-instar gypsy moth larvae in relation to population quality.** Oecologia 26:53–64.

"Field studies of dispersal by first-instar gypsy moth larvae, indicate that almost all larvae undergo an initial dispersal episode. However, in laboratory studies large larvae (from large eggs) disperse more frequently than small larvae (from small eggs) in the presence of favored food. Large larvae may be better adapted for dispersal. When

larvae encounter unacceptable food or are denied food, they disperse more frequently, . . . dispersal by small larvae is nearly as frequent as dispersal by large larvae. Factors affecting egg size may contribute to shifts in dispersal patterns of gypsy moth larvae and distribution of populations."
**Instars I–III: 1**

97. Cardé, R. T., C. C. Doane, and W. L. Roelofs.
1974. **Diel periodicity of male sex pheromone response and female attractiveness in the gypsy moth (Lepidoptera: Lymantriidae).** Can. Entomol. 106: 479–484.
"In field studies, gypsy moth males were attracted to synthetic cis-7, 8'epoxy-2- methyloctadecane (disparlure), the female sex pheromone, and virgin females from 0900 to 2000 [hours] (Eastern Standard Time). The greatest numbers of males were lured to the synthetic attractant or the calling female from 1100 to 1500 [hours]. These periods of male response are longer than reported in previous (1896 and 1932) New England investigations and suggest the possible recent evolution of a new diel rhythm of male sex pheromone response."
**Adults: 1**

98. Cardinal, J. A.
1967. **Control of the gypsy moth in Quebec** [in French English summary]. Phytoprotection 48: 92–100.
"The gypsy moth situation in Quebec has reached an alarming state and some drastic measures will be undertaken. Five counties are affected by this last outburst, covering some 20,000 acres. The records of its steady progress towards northern regions and its sporadic behavior since its introduction into Massachusetts in 1869 offer a constant challenge. Renewed strategy is necessary to face this progressing menace. The Canadian authorities are worried about its gradual adaptation to climate. Research is now oriented towards synthetic sex attractant that could be spread by plane over large areas to reduce population."
**Generation: 12**

99. Cardinal, J. A., and W. A. Smirnoff.
1973. **Experimental introduction of the nuclear polyhedral virus of *Porthetria dispar* L. (Lepidoptera: Lymantriidae) in the forest** [in French, English summary]. Phytoprotection 54: 48–50.
"A 4-year gypsy moth infestation in Huntingdon County is maintained in an almost endemic state by a viral infection of the larvae. Tentative dispersion of the virus into other gypsy moth-infested territories was made in forest by treating egg masses and foliage with a viral aqueous suspension; rearing of larvae was also successful in forest for subsequent use of viral suspension. There are very promising possibilities to create epizootic viral infections where the gypsy moth population is densely built."
**Eggs: 7; Generation: 7; Larvae: 7**

100. Ceballos, P. J.
1961. **An experiment on the reproduction of an ichneumonid *(Pimpla instigator F.)* in captivity** [in Spanish]. Bol. Serv. Plagas For. 4(8): 97–101.

101. Chapman, J. W., and R. W. Glaser.
1916. **Further studies on wilt of gipsy moth caterpillars.** J. Econ. Entomol. 9: 149–169.
From their studies the authors concluded that wilt is a true infectious disease that seems to be transmitted between generations through the egg. Some gypsy moths seem immune to it. It is filterable through Berkefeld "N" candles but not through Pasteur-Chamberland "F" filters. In their experiments the period from inoculation by feeding until death varied from 13 to 29 days. They worked with both American and Japanese gypsy moth stock. A new disease, which differed clinically and microscopically from wilt, attacked instars IV and V of the foreign stock. Numerous *Saccharomycetes* and *Micrococci* were isolated from the intestines of diseased animals, but no polyhedra were found in them.
**Eggs: 7; Instars IV–VI: 6; Larvae: 7**

102. Chu, Hai-Tsin.
1962. **Contribution to the ontogensis and biology of *Apanteles solitarius* Ratz., parasite of the gypsy moth *(Porthetria dispar* (L.))** [in Russian]. Vestn. Mosk. Univ. Biol. Pochvoved. 1962(6): 26–32.

103. Chu, Hai-Tsin.
1965. **Effect of *Apanteles solitarious* Ratz. larvae on the mesenteron of the gypsy moth *(Porthetria dispar* (L.))** [in Russian]. Vestn. Mosk. Univ. Briol. Pochvoved. 1965(4): 34–37.

104. Chugunin, Y.
1949. **Focal periodicity of gypsy moth outbreaks** [in Russian]. Zool. Zh. 28(5): 431–438.

105. Chugunin, Y. V.
1959. **Cycles of increase of pest insects and the microbiology method of controlling them**[In Russian, English summary] First Int. Conf. Insect Pathol. Biol. Control 1958: 81–93.
"The gypsy moth in the Crimea is a very suitable object for the study of natural control of the pest by microorganisms. In most cases, 3-year outbreaks of the pest occur in the climatic conditions of the locality. After this period a spontaneous liquidation of the populations by disease and parasites can be observed. The waves of the disease . . . [just] as the outbreaks, start at the southern shore of the peninsula and go to the north. Protozoa, fungi, and bacteria are involved in natural control of the outbreaks."
**Generation: 2,4,5,7,8**

106. Clement, G. E.
1917. **The gipsy moth in the woods.** Pages 1–16 *in* Control of the gypsy moth by forest management. U. S. Dept. Agric. Bull. 484.
Although at first the gypsy moth was thought to be omnivorous, it was later found that they prefer certain food plants. Young larvae do not eat conifers except for tamarack, which is not abundant in the gypsy moth region. Once established, an infestation in a wood will probably remain for as long as the food supply lasts, though the degree of infestation will vary. Among defoliated trees, oak has suffered the highest mortality owing to three factors: the presence of *Agrilus bilineatus*, whose damage is usually evident beneath the bark of all dead specimens; the fact that the gypsy moth region is the northern limit of white oak, causing further stress; and the tendency of oaks to be on the poorest sites. Pure stands of conifers are immune to serious damage; the percentage of unfavored hardwoods influence's the amount of damage. Dying trees harbor borers which can attack defoliated trees that would otherwise be able to recover. Young larvae can feed on shrubs and when older proceed to unfavored tree species. In a full stand, shrubs are shaded out. If the stand is properly managed, there are no shrubs. Trees of a favored species should not be eliminated because of the gypsy moth; rather, mature or defective trees should be removed.
**Oak stands: 15, 16, 25; All stands: 15; Non- oak stands: 15**

107. Clement, R. C., and I. C. T. Nisbet.
1974. **The suburban woodland: trees and insects in the human environment.** Audubon Conserv. Rep. 2. Mass. Audubon Soc., Lincoln, Mass.
This paper reviews and synthesizes work done on aspects of forest ecology, demonstrating that there is a natural balance between trees, insects, and other forest inhabitants. Details are given on the life system of the gypsy moth.
**Generation: 1,2,12; All stands: 15, 20**

108. Cointat, M.
1948. **Observations on an invasion of *Lymantria dispar* L. in the forest range of Uzès** [in French]. Rev. Eaux For. 86(1): 11–32.

109. Collado, J. G.
1931. **Notes on Spanish tachinids (Dipt.). I. Some parasites of caterpillars in El Escorial** [in Spanish]. Eos 7: 349–354.

110. Collins, C. W.
1915. **Dispersion of gipsy moth larvae by the wind.** U. S. Dep. Agric. Bull. 273, 23 p.
Wind is almost wholly responsible for the general spread of the gypsy moth in New England, as proven by experiments utilizing tanglefoot screens which caught larvae carried by wind as far as 13.5 miles. Larvae are sufficiently active at 55 °F to be caught by wind velocities ranging from 2 to 23 mph, although more dispersal activity occurs at temperatures of 65 to 85 °F. with wind velocities of at least 8 mph. Larvae have been caught at times when winds were blowing from all directions except the north, with the greatest numbers carried aloft by westerly winds. From the time the gypsy moth first appeared in Providence, R. I. in 1901, it spread at a rate of 5 miles per year northeast and 3 miles per year west, which tends to verify the data collected in connection with these screen experiments.
**Instars I–III: 1**

111. Collins, C. W.
1917. **Methods used in determining wind dispersion of the gipsy moth and some other insects.** J. Econ. Entomol. 10: 170–177.
Data were collected on long-distance wind dispersal of gypsy moth larvae across Cape Cod Bay off

the coast of Massachusetts, from an infestation 19 to 30 miles distant. Three or four other species of Lepidoptera larvae were also carried by the wind and caught in the traps.
**Instars I–III: 1**

112. Collins, C. W., and J. E. R. Holbrook.
1929. **Trapping *Calosoma* beetles.** J. Econ. Entomol. 22: 562–569.

A *Calosoma* beetle trap was designed by the authors for the purpose of obtaining a count of the number of beetles per tree or per given area. The trap construction is discussed as is the possibility of using the trap to collect large numbers of beetles for colonization.
**Larvae: 3; Pupae: 3**

113. Collins, C. W., and C. E. Hood.
1920. **Life history of *Eubiomyia calosomae*, a tachinid parasite of *Calosoma beetles.*** J. Agric. Res. 18: 483–497.

*E. calosomae* was first noted on *Calosoma sycophanta* in 1912, 6 years after its introduction to the United States. It has been bred from *C. sycophanta, C. frigidum,* and *C. calidum* and is very widespread. It is believed to be native to New England. The flies are more active during late afternoon and early morning when beetles are quiescent. They oviposit on the exoskeleton singly or in small groups of eggs. Larvae hatch soon after being deposited (3 to 12 hours) and enter the host immediately, probably through spiracles. First and second instar larvae attach to host trachae, hibernating at second instar when the host *Calosoma* burrows beneath the ground. Host and parasite both resume activities around the same time in May or June. Third-instar larvae move freely in the host body cavity where blood and fats have been reduced by parasite feeding. *Calosoma* is further weakened by the process of surfacing after hibernation, and it dies on the ground surface or just below. The fly pupates in the body cavity or under the elytra after death of the host. There are two generations per year: Adults issue in May to June and again in July to August. Many of the second generation dies because most *Calosoma* hibernate by July 15 and no hosts are available. This keeps down the parasite population. If the range of *C. calidum* were to overlap with that of *C. sycophanta,* the rate of parasitism would increase because of a longer host season. The highest rate of parasitism on *C. sycophanta* was 3.4 percent, but the average on *C. calidum* is 4.4 percent. One secondary parasite has been reared from pupae of *Eubiomyia: Chalcis* larvae.

114. Collins, C. W., and S. F. Potts.
1932. **Attractants for the flying gipsy moths as aids in locating new infestations.** U. S. Dept. Agric. Tech. Bull. 336.

"Male gypsy moths are strongly attracted to living virgin females. A scent is given off from the vicinity of the copulatory-pouch opening and is sensed by the male through its antennae. Some males fly as far as 2.38 miles, but usually the distance of flight is much shorter; and catches of males are seldom made at traps over 1/2 mile distant from a colony. . .Certain extracts made from the region of the female genitalia attract males. . .[but] none of the attractant was found in glands of the reproductive system internally. . .The attractant is of a complex fatty nature and is saturated. When exposed, it is active for several weeks, a period equivalent to the flight season of the males. . ."
**Adults: 1,13**

115. Collins, C. W., and W. L. Baker.
1934. **Exploring the upper air for wind-borne gipsy moth larvae.** J. Econ. Entolol. 27: 320–327.

Field work has shown wind to be the chief agent of larval dispersal. Especially important are the warm surface westerlies which over a 40-year period caused the gypsy moth to spread 2-1/2 times as rapidly to the northeast and southeast as to the northwest and southwest. In the 1932 and 1933 seasons, an airplane with sticky traps mounted below one wing flew over southeastern Massachuetts. The flights were made daily during the period of peak larval hatch when ground temperatures were higher than 70°F. During 1932, nine flights and 40 screen exposures were made at altitudes ranging from 300 to 5000 feet from May 10 to 12. The average trap exposure time was 12 minutes, 11 seconds. Despite weather conditions unfavorable for maximum larval activity, one first-instar larva was caught at the 300- to 500-foot range and two at 1000 feet. In 1933, with a newly designed trap, 14 flights and 62 exposures were made between May 10 and 23 at altitudes ranging from 500 to 3000 feet. The average exposure time was 11 minutes, 27 seconds, and the exposure space doubled

to 2 square feet. Only one gypsy moth larva was caught at 2000 feet. Despite the small numbers caughts, the authors found the results satisfactory because the size of the sample was minute considering the cubic feet of air above the infested area.
**Instars I–III: 1**

116. Collins, C. W.
1934. **Natural enemies of the gypsy moth, brown-tail moth, and some other forest and shade tree pests in Massachusetts.** Mass. Comm. Conserv. State For. Annu. Rep. 1933: 31–32.

From 1929 to 1933 collections and observations were made in designated 10-acre woodland areas in New England to determine the percentage of parasitism and predation in each life stage. Owing to a large increase in gypsy moth infestation, the percentage of parasitism and predation declined from 1932 to 1933 despite an increse in the number of insect enemies.
**Generation: 2,3,4**

117. Collins, D. L.
1960. **Population studies of the gypsy moth (*Porthetria dispar* L.) in New York State.** Pages 215–218 *in* Proc. 11th Int. Congr. Entomol., 1960, Vol. II, Sec. VIII For. Entomol.

This paper outlines some studies that were undertaken in New York State in the late 1950's to investigate factors affecting gypsy moth populations dynamics.
**Generation: 1,2**

118. Collins, S.
1961. **Benefits to understory from canopy defoliation by gypsy moth larvae.** Ecology 42: 836–838.

"Two observations suggest that light intensity is the critical factor controlling elongation of maple in the woods. First, the halting of elongation in the undefoliated woodland coincide with the estimated canopy closure. Second, in the defoliated stand where the understory was not fully shaded, elongation continued past the normal stopping time. It did stop when refoliation occurred. . .The chronology of elongation, defoliation, and refoliation leaves no doubt that maple could exploit increased light intensity [caused by oak defoliation]"
**Oak stands: 15, 21; All stands: 20; Non-oak stands: 24**

119. Connecticut Agricultural Experiment Station, New Haven.
1915. **The gypsy moth.** Conn. Agric. Exp. Stn. Bull. 186. Entomol. Ser. 21. 24 p.

Although several enemies of the gypsy moth are native to the United States, none is effective in holding it in check. *Calosoma scrutator* Fabr. has been found under burlap bands. In captivity one ate 137 gypsy moth larvae in 13 days. *C. calidum* and *C. frigidum* are also predatory. Eggs of *Tachina mella* Walk. were observed on the backs of gypsy moth larvae, and tachinid adults emerged from pupae. The gypsy moth pupae were closely packed with fly puparia, but only one adult emerged per pupa. Predaceous soldier bugs eat gypsy moth larvae. More than 40 species of birds were seen feeding on the gypsy moth in different stages, but only a few are useful, these include the cuckoo, oriole, robin, catbird, bluejay, crow, chipping sparrow, chickadee, and vireo. Wilt disease may be indigenous to the United States; it killed many larvae from 1913 to 1915.
**Generation: 9; Larvae: 3,4,6**

120. Corliss, J. M.
1955. **Damage to our forests caused by the gypsy moth in 1953.** J. Econ. Entomol. 48: 263–264.

In 1952 unusual increases in egg mass populations were noted, and extensive defoliation was predicted for 1953 unless large-scale spraying was undertaken. An unprecedented increase in defoliated areas did occur (1951:21,314 acres; 1952:293,052 acres; and 1953:1,500,000 million acres). Records of the previous 25 years show decided cyclical recurrence of defoliation peaks following minor crests at approximate 8-year intervals: 1929:551,133 acres; 1937:1, 487,077 acres. Causes of the cycles are obscure. Retardation in growth is shown to be directly proportional to percentage of defoliation. Mortality of young white pine is substantial in defoliated mixed stands. There is increasing evidence that defoliation in two successive seasons (or one complete stripping in some cases) is fatal to softwoods, particularly hemlock. Long-term records for losses to softwood species are not available. Three tornadoes in heavily infested regions on June 9, 1953 may have dispersed the gypsy moth. Larvae were in the third instar

and could have been carried aloft. This is disputed by some meterologists and entomologists who point to wind velocities of 350 mph and subfreezing temperatures.
**All stands: 15,18,24,26; Generation: 2; Instars I–III:1, 12**

121. Cosenza, B. J., and J. D. Podgwaite.
1966. **A new species of *Proteus* isolated from larvae of the gypsy moth *Porthetria dispar* (L.).** Antonie van Leeuwenhoek J. Microbiol. Serol. 32:187–191.
A slime-producing bacterium was isolated from living and dead gypsy moth larvae and named *Proteus myxofaciens*. It fermented glucose but not lactose, was oxidase-negative, hydrolyzed urea, deaminated phenylalamine, and produced $H_2S$.
**Larvae: 5**

122. Cosenza, B. J., and F. B. Lewis
1966. **Taxonomic considerations of four "wild"-type crystalliferous bacilli and their toxicity to larvae of the gypsy moth, *Porthetria dispar*. J. Invertebr. Pathol. 8:520–525.**
"Four strains of wild-type spore-forming, crystalliferous bacilli were isolated from dead or diseased gypsy moth larvae. . .Results showed that the four crystalliferous bacilli conform to the description of *B. thuringiensis* var. *thuringiensis* Berliner. . .All crystalliferous isolates were found to be pathogenic. In feeding trials employing 3900 instar II larvae, significant differences were observed in the toxicity of the laboratory-prepared, crystalspore powders of each "wild" strain."
**Instars I–III: 5; Larvae: 5**

123. Crawford, J. C.
1910. **Technical results from the gyspy moth parasite laboratory II Descriptions of certain chalcidoid parasites.** U. S. Dept. Agric. Bur. Entomol. Tech. Ser. 19, part 2:13–24.
*Chalcis* species known to occur in the United States are included in a key to the genus along with those species introduced purposely as parasites of the gypsy or brown-tail moths and those accidentally included with material shipped to the gypsy moth laboratory. A new species, *Chalcis fiskei*, is described. A key separating the common American species of *Hypopteromalus* from two exotic forms and a key differentiating the Japanese species of *Pleurotropis* are given. Appropriate species of these genera are described as are *Perilampus inimicus* and *Dimmockia secundus*, both new species.
**Generation: 4**

124. Crossman, S.S.
1917. **Some methods of colonizing imported parasites and determining their increase and spread.** J. Econ. Entomol. 10: 177–183.
The following egg parasites are in the family Encyrtidae: *Anastatus bifasciatus* Fonsc. and *Schedius kuvanae* How. *Schedius* hibernates as an adult, ovipositing in gypsy moth eggs 1 to 2 weeks prior to hatching in spring. This spring generation carries the species through the summer. In July, soon after gypsy moth eggs are laid, *Schedius* attacks them, and a generation is produced every 25 days until the onset of cold weather, giving four generations and a partial fifth per year. Parasitism by *Schedius* is ascertained by exit holes on eggs. *Schedius* spreads more rapidly than *Anastatus*, which has one generation per year. It oviposits in gypsy moth eggs soon after they are laid. Parasite larvae devour egg contents before the embryo develops, remaining in the host egg through the year until a week or so before gypsy moth eggs are laid. They then pupate, emerge, and attack new eggs. Laboratory rearing and colonization are discussed.
**Eggs: 4**

125. Crossman, S. S.
1922. **Apanteles melanoscelus, an imported parasite of the gipsy moth.** U. S. Dep. Agric. Bull. 1028.
This paper, covering the history, dispersal, and biology of *Apanteles melanoscelus*, concludes that this parasite is firmly established in New England and is spreading despite heavy secondary parasitism. Its value is enhanced by its ability to complete its life cycle on several native insects. It has two generations per year on the gypsy moth and is very abundant in many localized areas.
**Instars I–III: 4**

126. Crossman, S. S., and R. T. Webber.
1924. **Recent European investigations of parasites of the gipsy moth *Porthetria dispar* (L.) and the brown-tail moth, *Euproctis chrysorrhoea* L.** J. Econ. Entomol. 17: 67–76.
In investigating the gypsy moth and brown-tail moth situation in Europe, the authors found a medium-intensity infestation at Debrezcen, Hun-

gary, from which they collected over 100,000 gypsy moth larvae and pupae and reared nearly 44,000 parasites. Experimental work at Debrezcen indicated that 71 percent of the last two larval stages were killed by the parasites *Apanteles fulvipes* Hal., *Blepharipa scutellata* R. D., *Carcelia gnava* Meig., *Compsilura concinnata* Meig., *Lydella nigripes* Fall., *Parasetigena segregata* Rond., *Sturmia gilva* Hartig., *Tachina larvarum* L., and *Zenillia libatrix* Panz. *P. segregata* killed 40 percent of the larvae. In Europe the gypsy moth has periods of abundance followed by periods of inconspicuousness. At the time of writing there were several places in central Europe with small areas of light to medium infestations, and indications were that *P. dispar* was on the increase in some regions.
**Instars IV–VI: 4; Generation: 2**

127. Crossman, S. S.
1925. **Foreign travel and entomologists met while searching for enemies of the gipsy moth.** J. Econ. Entomol. 18: 164–172.

This is an anecdotal and factual background to early parasite importation work. It describes the author's meetings with foreign entomologists, their work, and the extent of the gypsy moth problem in each area. As a result of the author's investigations, six European laboratories (one each in Hungary, Poland, Bulgaria, and Yugoslavia and two in Spain) sent over 100,000 tachinid puparia of the species *Blepharipa scutellata* R. D., *Carcelia gnava,* Meig., *Compsilura concinnata* Meig., *Lydella nigripes* Fall., *Parasetigena segregata* Rond., *Tachina larvarum* L., *Tricholyga grandis* Zett., *Zenillia libatrix* Panz., *(Zygobothria) Sturmia gilva* Hartig. to the Melrose Laboratory in Massachusetts. More than half of these were *P. segregata.* Small numbers of other parasites and predators were also sent.
**Larvae: 4**

128. Crossman, S. S.
1925. **Two imported egg parasites of the gipsy moth *Anastatus bifasciatus* Fonsc. and *Schedius kuvanae* Howard.** J. Agric. Res. 30: 643–675.

*Schedius kuvanae* Howard was imported from Japan, and *Anastatus bifasciatus* Fonsc. was received with material from Japan and Europe. *S. kuvanae* appeared to be more common in Japan than *A. bifasciatus.* When both species were present in the same collection of eggs from Japan, the percentage of parasitism was low. The percentage of parasitism by *Schedius* ranged from 0 to 33.3 percent in different collections, while parasitism by *Anastatus* never exceeded 2 to 3 percent. The percentage of *Anastatus* parasitism in material from Europe ranged from 0 to 25 percent. Detailed biological information is given on these two *Encyrtidae* (Hymenoptera), and the results of colonization in the United States are discussed.
**Eggs:4**

129. Cuéllar, A. R.
1958. **Suggestion about the biological fight against *Lymantria dispar* in the egg stage** [in Spanish]. Bol. Serv. Plag. For. 1: 41–53.

Biological control in the egg stage of the gypsy moth is discussed, with special attention to the thermal requirements of gypsy moths and parasites. Twenty-five years ago, the release of *Anastatus disparis* Ruschka and *Ooencyrtus kuwanae* How. were involved in the decline of *L. dispar,* although it was not proven that the parasites were solely responsible for this decline. However, in place of the gypsy moth came *Tortrix viridana, Malacosoma neustria, Ephesia nymphaea,* and *Catocala nymphagoga.*
**Eggs: 2,4,12,13**

130. Culver, J. J.
1919. **A study of *Compsilura concinnata,* an imported tachinid parasite of the gipsy moth and the brown-tail moth.** U. S. Dep. Agric. Bull. 766.

*Compsilura concinnata* Meigen was introduced into Massachusetts in 1906 as a parasite of the gypsy moth and brown-tail moth. Its distribution in Europe, colonization in the United States, classification, life history, seasonal history, parasites, hosts, and economic importance are discussed.
**Larvae: 4**

131. Cushman, R. A.
1927. **New species and new forms of Ichneumonidae parasitic upon the gipsy moth parasite, *Apanteles melanoscelus* (Ratzeburg).** J. Agric. Res. 34: 453–458.

The efficacy of *Apanteles melanoscelus* (Ratzeburg), an introduced parasite of the gypsy moth, is hampered by the activities of hyperpara-

sites native to the United States. *Hemiteles apantelis* n.sp., *Gelis apantelis* n.sp., *G. inutilis* n.sp., *G. nocuus* n.sp., *G. bucculatricis* (Ashmead), and *G. urbanus* (Brues) are described.
**Instars I–III: 4**

132. Davis, I. W.
1920. **Gipsy and brown-tail moth work in 1919.** Conn. Agric. Exp. Stn. Bull. 218: 135–144.
Since there had been no marked apparent wind spread of the gypsy moth since 1916, the number of egg clusters in infested towns decreased and the quarantine was partially lifted. The budget allotment for gypsy and brown-tail moth suppression and imported nursery stock inspection was $70,000 for the 2-year period ending June 30, 1921; it had been $40,000 for the preceding 2-year period. A town-by-town account of work done on gypsy moth suppression is given.
**Instars I–III: 1**

133. Delassus.
1923. ***Liparis dispar* in Algeria** [in French]. Rev. Agric. Afr. Nord. 21(211): 520–524.

134. Delassus.
1925. **The struggle against *Liparis dispar* in the mountains of Edough** [in French]. Rev. Agric. Afr. Nord. 23(327): 334–336, (328): 348–352.

135. Diaz, B.
1923. **Parasites of *Lymantria dispar* L.: *Apanteles vitripennis*** [in Spanish]. Rev. Fitopatol. 1(2–3): 80–82.

136. Dimitrievskaya, O. E.
1956. **Gypsy moth as a pest of coniferous forests** [in Russian]. Lesn. Khoz. 1956(10): 80.

137. Dissescu, G.
1963. **Research on the biology of the principal oak tree defoliating caterpillars.** Report on Ph.D. thesis. Brasov Polytech. Inst. (For. Dep.), Brasov, Romania.
Eight oak defoliators were studied from 1954 to 1961 in the forests of the plains region of Romania to help elucidate factors in their population dynamics. Outbreaks of the gypsy moth were more frequent than those of the other insects studied. Within one gradation, dependent on forest conditions, gypsy moth fertility varied from 200 to 700 eggs, a greater range than for any of the other species studied. Equations were derived to predict average fertility (F) from the weight in grams (W) of egg clusters from which hair had not been removed: $F = 1198.16W + 38.59$ (use January to March) and $F = 1204.56W + 40.89$ (use September to October). Error was + 2–3 percent. Less satisfactory equations were derived using the weight of the egg cluster without hair, the volume of the cluster without hair, and the product of the dimensions of the cluster. To determine fertility from the pupal stage, the female weight the day the moths emerged was used in the equation $F = 503.71W - 108.97$. Mortality of gypsy moth larvae and pupae varied, depending on the source of the material. The greater mortality in material from sunnier places (forest margin or upper crown), may have been due to a higher density of larvae there. The closer a population was to crisis, the higher the percentage of mortality. Mortality of prepupae and pupae increased when larvae had consumed all of a favored food and were forced to switch to a less favored species. Three fourths of the total diet was consumed in the last instar. Males consumed 28.8 percent of what females consumed. The gypsy moth female was the most voracious of the species studied. In addition to foliage eaten, defoliation was caused by larvae cutting off leaves. Females cut off 12.9 percent in relation to what was eaten, and males 6.2 percent. A linear relationship was found between amount eaten and fertility: average quantity of oak leaves eaten in $mm^2 = 103.27\ x$ average fertility of females hatched from larvae + 78679.67. The average total diet of a gypsy moth caterpillar could vary 2.2 times when average fertility ranged between 100 and 750 eggs. The data demonstrated that less defoliation occurs in the crisis phase than in the eruption phase with equally dense populations.
**Oak stands: 15; Fecundity: 2,13; Generation: 2,12**

138. Dissescu, G., and I. Ceianu.
1967. **Observations on the parasitization of eggs of *Lymantria dispar* (L.) by *Anastatus disparis* Ruschka** [in Romanian]. Rev. Padurilor 82(9): 470–475.

139. Doane, C. C.

1967. **Bioassay of nuclear-polyhedrosis virus against larval instars of the gypsy moth.** J. Invertebr. Pathol. 9: 376–386.

"The relative susceptibility of three larval instars of the gypsy moth, *Porthetria dispar*, to a nuclear-polyhedrosis virus was studied by bioassay in the laboratory. The $LC_{50}$ values for 1st-, 2nd-, and 3rd-instar larvae were 0.23, 2.3, and 2.5 polyhedral inclusion bodies per $mm^2$ of food surface (PIBs/$mm^2$). $LT_{50}$ values of larvae fed on serial-dilution concentrations of 69,879 to 0.06 PIB's/$mm^2$ were established. From measurements of the amount of feeding on surfaces treated with 69 PIB's/$mm^2$, a concentration producing approximately 100 percent mortality, the average doses were 2233, 11,690, and 25,197 PIB's, respectively. Ingestion of PIB's was initially benign and, with heavy doses, depended on their concentration on the food. The effects of low doses on molting, pupation, and adult emergence were observed. If the larvae survived two molts following exposure to the virus, no heavy mortality occurred later. The lowest concentration preventing a second molt in the three instars was 69 PIB's/$mm^2$."

**Larvae: 7**

140. Doane, C. C.

1967. **Pathogens of the gypsy moth.** Proc. Int. Colloq. Insect Pathol. Microb. Control, 1966. 6: 200–203.

A nuclear polyhedrosis virus and *Streptococcus faecalis* were tested for their pathogenicity to the gypsy moth. Two test series were run with the virus: Series I larvae were exposed to heavy doses at 24°C, and Series II larvae were exposed to lighter doses at 28°C. A concentration of 70 polyhedral inclusion bodies (PIB's)/$mm^2$ was used in both series, causing total mortality of instar III-larvae at 28°C, with 30 percent survival at 24°C. $LT_{50}$ times for various concentrations of PIB's/$mm^2$ are given for different larval stages as are $LC_{50}$ concentrations. Large numbers of polyhedra were found in adults from treated larvae; comparatively low numbers of polyhedra were found in 60 percent of adults from untreated larvae, which nevertheless points up the problem of latent infection. A second virus, probably cytoplasmic, was found in the gut wall of many larvae. *S. faecalis* was studied because of its association with polyhedrosis disease. However, it may be able to multiply only when the viral disease becomes acute.

**Adults: 7; Larvae: 5,7**

141. Doane, C. C.

1968. **Changes in egg mass density, size, and amount of parasitism after chemical treatment of a heavy population of the gypsy moth.** J. Econ. Entomol. 61: 1288–1291.

"Applications of a short residual phosphate, Gardona* (2-chloro-1- (2,4,5-trichlorophenyl) vinyl dimethyl phosphate) applied in 50-acre plots against dense populations of the gypsy moth, *Porthetria dispar* (L.), protected foliage but prolonged the outbreak by allowing numerous larvae to survive. In untreated woods, starvation and polyhedrosis reduced the number of larvae to a lower level. A study of the eggs of the succeeding generation showed that there were more egg masses in the treated plots and that they were of larger size than those outside the plots. There was also less parasitism by the egg parasite *Ooencyrtus kuwanae* (Howard) inside than outside the plots. The level of parasitism throughout the test area was high compared with that in previous reports."

**Eggs: 4,12; Larvae: 7,12,13**

142. Doane, C. C.

1968. **Aspects of mating behavior of the gypsy moth.** Ann. Entomol. Soc. Am. 61: 768–773.

"Females *in copulo* for periods of 1 to 4 minutes produced relatively few, scattered, infertile eggs while those mated 8 minutes or more produced fertile eggs in normal egg masses. An increasing number of females were fertilized during copulation periods of 5, 6, and 7 minutes. There was some evidence that normal egg-laying behavior may be released in unfertilized females. Certain of the females mated for periods of 5, 6, and 7 minutes; although sterile, they behaved like mated females and deposited egg masses normal in both appearance and number of eggs."

**Adults: 1; Fecundity: 1**

143. Doane, C. C.

1970. **Field application of a *Streptococcus* causing brachyosis in larvae of *Porthetria dispar*.** J. Invertebr. Pathol. 17: 303–307.

"A motile strain of *Streptococcus faecalis* originally isolated from a naturally infected larva and tested for pathogenicity under laboratory conditions was tested in the field. Mistblower sprays

prepared from broth cultures induced brachyosis in gypsy moth larvae feeding in apple trees. One application was made against larvae in late 2nd and early 3rd instar, and a second application was tested against larvae in the 4th instar. The test demonstrated the ability of the bacterium to produce disease and prevent defoliation even in an area with a heavy population . . . Epizootic outbreaks of disease in dense larval populations commonly occur with these organisms acting in a density-dependent manner. NPV is transmitted from generation to generation on the egg surface. Mortality, as a direct result of acquisition of the virus from the egg, occurs almost solely in the first instar." Cadavers of first-instar larvae probably are the inoculum source for larva-to-larva transmission. It is not known how streptococci are transmitted from generation to generation.

**Eggs: 7; Generation: 5; Instars I–III: 7; Larvae: 5**

144. Doane, C. C., and J. J. Redys.
1970. **Characteristics of motile strains of *Streptococcus faecalis* pathogenic to larvae of the gypsy moth.** J. Invertebr. Pathol. 15: 420–430.

"A bacterial disease of larvae of the gypsy moth, *Porthetria dispar,* is caused by infection of the gut with a streptococcus. The morphological, biochemical, and serological features of the organism were consistent with those of *Streptococcus faecalis.* The bacterium is ingested with food, multiplies in the digestive tract, and causes diarrhea. The diarrheic discharge contains a high concentration of infectious streptococci. The gut, especially the foregut, becomes distended with liquid from the hemocoelom. Streptococci are found in especially high concentration in the midgut. The infected larva does not feed, and as liquid is lost continually, body length decreases markedly and death occurs in 3 to 15 days. The cadavers usually have a characteristic mummified or desiccated appearance. Serological studies with antisera prepared by immunizing rabbits with several isolates indicate that at least three distinct serotypes were isolated from infected larvae. They appear to be serologically different from noninsect *S. faecalis* strains tested. It is suggested that this antigenic difference may form the basis of pathogenicity of the species. A pilot study revealed that an immunofluorescence technique may be an extremely valuable tool in identifying these organisms in insects and in determining their distribution in nature."

**Larvae: 5**

145. Doane, C. C.
1970. **Primary pathogens and their role in the development of an epizootic in the gypsy moth.** J. Invertebr. Pathol. 15: 21–33.

"The development of an epizootic was studied in a dense population of larvae of the gypsy moth, *Porthetria dispar.* The two pathogens involved were a nuclear polyhedrosis virus and a variant of *Streptococcus faecalis.* It was known that there was approximately 10 percent acute infection from transovum transmission of the nuclear polyhedrosis virus. The origin of the initial inoculum of the variant of *S. faecalis* is unknown, but it became common in the second and later instars. The behavior of the larvae increased the relative density of the population and enhanced the rate of larva-to-larva spread of the pathogens. Larvae in the first four instars fed most heavily in the tops of trees, and dead larvae accumulated on the upper surfaces of the leaves. These cadavers disintegrated and adhered firmly to the leaves, forming an abundant source of inoculum for feeding larvae. This occurred early enough to account for the later, massive increase in disease. Results from counts in the field and collections of larvae reared in the laboratory indicated that there was an increasing rate of infection and mortality that reached a climax when larvae were in the last instars. The threatened defoliation did not occur, and the population declined sharply. Although the nuclear-polyhedrosis virus appeared to be most important, up to 50 percent of the larvae in some collections were killed by the variant of *S. faecalis.* Observations indicated that the epizootic was density-dependent and that the rapid spread of pathogens in the susceptible population was enhanced by the behavior of the larvae during the early instars."

**Larvae: 1,5,7**

146. Doane, C. C., and P. W. Schaefer.
1971. **Field observations on the flight activity of *Calosoma sycophanta* (Coleoptera: Carabidae).** Ann. Entomol. Soc. Am. 64: 528.

This is the first report that adult *Calosoma sycophanta* are strong and agile fliers. They were observed flying upwind to an apple orchard infested with gypsy moths on a hot (85–87°F), humid day

in 1965 and again in flight under similar conditions in June 1970.
**Larvae: 3**

147. Doane, C. C.
1971. **A high rate of parasitization by *Brachymeria intermedia* (Hymenoptera: Chalcididae) on the gypsy moth.** Ann. Entomol. Soc. Am. 64: 753–754.

*Brachymeria intermedia* is occasionally of primary importance as a gypsy moth parasite in warm Mediterranean countries. In 1911 in Sicily, 15,567 parasites emerged from 16,500 pupae. The more usual rate is 4 percent, which was the average in a study in Spain and Portugal. In New England (1966, 1967, and 1971) Leonard found a 0.3 to 4.8 percent range. In Connecticut in January, a higher percentage was found in places where the canopy was open and along the forest edge. The area had been heavily defoliated the previous year. In the Mediterranean region, most cases of high *B. intermedia* parasitism were in areas of high defoliation.
**Pupae: 4,12**

148. Doane, C. C., and R. T. Cardé.
1973. **Competition of gypsy moth males at a sex-pheromone source and a mechanism for terminating searching behavior.** Environ. Entomol. 2: 603–605.

"*Porthetria dispar* (L.) males exhibiting pheromone orientation or searching behavior may be recognized by slow, slightly zigzag forward flight, with body held at an angle of roughly 45 degrees to the horizontal plane and antennae directed up and forward. The mean search time for males searching alone at a natural pheromone source was 20.52 ± 3.88 seconds; then males ended searching behavior. After termination of searching behavior, males held the body more horizontally, and forward flight was direct, rapid, and usually up or across the path of wind until they were lost from sight. Two males at a natural sex pheromone source touched wing tips in a mean time of 4.38 ± 1.01 seconds of arrival of the second male. Searching behavior was terminated by rapid wing-touching within two seconds in one or both males in 86 percent of the contacts. The evolutionary significance of this aggressive competition may be that it tends to disperse males from dense to sparse populations, thereby increasing the chance of males mating with isolated females, which have greater reproductive potential than females from dense populations."
**Adults: 1; Fecundity: 2**

149. Dobrivojević, K.
1963. **Some observations on the mass occurrence of gypsy moth in the district of Valjevo from 1947–1961** [in Serbo-Croatian, English, summary]. Zast. Bilja 14(76):677–692.

There were two gradations (1946–1950, 1953–1957) and two periods of latency of the gypsy moth in Valjevo during the observation period, 1947 to 1961. Owing to variations in the terrain and in the plant communities, the gypsy moth appeared in both dense and sparse populations. Greatest damage occurred in the flatlands. Conditions were warmer and drier in the first gradation, damage was greater than in the second gradation. Foci of the gypsy moth were in oak and elm habitats. A polyhedrosis epidemic appeared over the whole territory in the gradation crisis. The birds *Oriolous galbula* L. and *Sitta europea* L. were important predators of larvae and eggs, respectively. Competing species were *Aporia oratégi* L. and *Malacosoma neustria* L.
**All stands: 18; Eggs: 9; Generation: 2,12; Larvae: 7,9; Oak stands: 15; Non-oak stands: 15**

150. Domin, K.
1928. **Aftereffects of the influence of the gypsy moth on forest underbrush in Brdech** [in Czechoslovakian]. Veda Prir. (Prague). 9(9): 262–264.

151. Dowden, P. B.
1933. ***Lydella nigripes* and *L. piniariae*, fly parasites of certain tree-defoliating caterpillars.** J. Agric. Res. 46: 963–995.

In Europe, *Lydella nigripes* is a widespread, though minor, parasite of both *Porthetria dispar* and *Nygmia phaeorrhoea*. The literature reports it overwintering as a first-instar larvae in *Bupalus piniarius* L., but this study shows that two species are involved. *L. piniariae* is a parasite of *B. piniarius* and does not attack hairy larvae. It has only one generation per year and is able to complete development in only three host species. It is considered an important factor in controlling the pine geometrid moth. *L. nigripes* has three to four generations per summer, is exceptionally polyphagous, and shows a preference for hairless lar-

vae, although it will larviposit in hairy larvae. Owing to these limitations and to the fact that it is in competition with aggressive larval parasites, such as *Compsilura concinnata,* it is not an efficient parasite of the gypsy or brown-tail moth and has not been able to establish itself in the United States.
**Larvae: 4,12**

152. Dowden, P. B.
1934. ***Zenillia libatrix* Panzer, a tachinid parasite of the gypsy moth and the brown-tail moth.** J. Agric. Res. 48: 97–114.
Early in the 20th century, when the gypsy moth (*Porthetria dispar* (L.)) and the brown-tail moth (*Nygmia phaeorrhoea* Don.) were being reared in Europe for the purpose of collecting natural enemies to export to the United States, *Zenillia libatrix* was shown to be a parasite of minor importance. Oviposition is on leaf edges, and reproductive capacity varies with the size of the fly (from 820 to 2439 eggs in this study). It is widespread in Europe but is inefficient as a parasite of the gypsy moth because it is very polyphagous and is double brooded, so that many individuals complete a generation in the fall after host larvae have gone into hibernation.
**Larvae: 4,12**

153. Dowden, P. B.
1935. ***Brachymeria intermedia* (Nees), a primary parasite and *B. compsilurae* (Cwfd.), a secondary parasite of the gypsy moth.** J. Agric. Res. 50: 495–523.
*Brachymeria intermedia* is a European parasite of gypsy moth and other Lepidoptera pupae. *B. compsilurae* is a native North American parasite of *Compsilura concinnata* and *Sturmia scutellata,* imported tachinid parasites of the gypsy moth. A lieterature review of the genus *Brachymeria* is given, as is biological information on both species. *B. intermedia* overwinters as an adult, passing through two or possibly three generations per year. It oviposits in a host pupa and requires a development time from egg to adult of from 18 days in August to 62 days in September. It has five larval instars. *B. compsilurae* is known to parasitize only tachinids. It overwinters as a full-grown larva within the host puparium and is univoltine in single-generation hosts and multivoltine in multibrooded hosts. It oviposits through the primary lepidopterous host pupa or larva, locating the tachinid maggot probably by odor. Development from egg to adult requires 23 to 28 days for males and 25 to 31 days for females. The five larval instars bear no resemblance to those of *B. intermedia,* although the adults are morphologically similar.
**Pupae: 4**

154. Dowden, P. B., and H. L. Blaisdell.
1959. **Gypsy moth.** U. S. Dep. Agric. For. Serv., For. Pest Leaflet 41, 4 p.
This article covers distribution of the gypsy moth as of 1959; description of its life history and habits, including the larval and adult stages, host trees and damage; and natural and applied control. No data are provided.
**Generation; 2, 4; Larvae: 1; All stands: 15**

155. Dowden, P. B.
1961. **The gypsy moth egg parasite, *Ooencyrtus kuwanai,* in southern Connecticut in 1960.** J. Econ. Entomol. 54: 876–878.
The life cycle of *Ooencyrtus kuwanai* consists of one spring generation and three summer generations. About 20 days are required for complete development from egg to adult. As the season progresses, the developmental time increases. Newly oviposited gypsy moth eggs are parasitized by adult *O. kuwanai* from the spring generation. As each generation emerges it parasitizes more eggs. The last summer generation overwinters as adults and parasitizes overwintering gypsy moth eggs in the spring. Parasitism averages 30 to 40 percent. The major limitation is the inability of *O. kuwanai* to reach eggs buried in the egg mass.
**Eggs: 4**

156. Drees, H., and H. Schwitulla.
1956. **Tests on the use of *Apanteles solitarius* Ratz. W. against *Lymantria dispar* L.** [in German]. Anz. Schaedlingskd. 29(6): 81–85.

157. Dunbar, D. M., R. M. Weseloh, and G. S. Walton.
1972. **A fungus observed on egg clusters of the gypsy moth, *Porthetria dispar* (Lepidoptera: Lymantriidae).** Ann. Entomol. Soc. Am. 65: 1419–1421.
*Paecilomyces farinosus* (Dickson ex. Fries) Brown and Smith, an omnivorous entomogenous imperfect fungus, readily grows as a saprophyte on waste products in gypsy moth eggs parasitized by

*Ooencyrtus kuwanai* (Howard). *P. farinosus* did not parasitize intact gypsy moth eggs in the laboratory.
**Eggs: 4,8**

158. Dunbar, D. M., and G. R. Stephens.
1975. **Association of twolined chestnut borer and shoestring fungus with mortality of defoliated oak in Connecticut.** For. Sci. 21: 169–174.
Following severe oak defoliation (1969–1971) by the gypsy moth and elm spanworm, increasing oak mortality was seen in Connecticut. A study was undertaken in 1972 to determine if *Agrilus bilineatus* (Weber) and *Armillaria mellea* (Vahl.) Quel. were contributing to this increase, as they were reported to have done in West Virginia, Pennsylvania, and New Jersey on previously defoliated trees. "During 1969 to 1973, mortality of previously defoliated oak on 13 0.04-ha plots in nine Connecticut towns ranged from 18 to 79 percent. Girdling by the twolined chestnut borer, *A. bilineatus* (Weber), but not attack by the shoestring fungus, *A. mellea* (Vahl.) Quel., appeared to be the main cause of mortality. Emergence holes of *A. bilineatus* (Weber) were found at breast height on 50 to 100 percent of oaks dead at least 1 year, and all dying (21) and recently dead (36) trees contained live larvae. Of 21 apparently healthy trees sampled, 43 percent had been attacked (mainly in the upper bole) by *A. bilineatus* (Weber). In contrast, *A. mellea* (Vahl.) Quel. mycelial fans were present in none of the living, 31 percent of the recently dead trees, and 80 percent of the trees dead 1 year."
**Oak stands: 15,16,25**

159. Edel'man, N. M.
1953. **The influence of the feeding regime on the development of gypsy moths *(Lymantria dispar)* and poplar leafeaters (*Melosoma populi* and *M. tremulae*** [in Russian]. Entomol. Obozr. 33: 33–46.
When nutritional conditions are optimal growth of these insects is completed in a shorter time. For example, *L. dispar* finished its growth on oak 8 days sooner than on birch. Weight is also correlated with the quality of the nutrition. Data are also given on the N reserves, respiratory coefficient, and fat content under different nutritional conditions.
**Generation: 13**

160. Edel'man, N. M.
1956. **The biology of *Lymantria dispar* L. under conditions of the Kubinskogo district of the Azerbaijan S. S. R.** [in Russian]. Zool. Zh. 35(4): 572–582.

161. Edel'man, N. M.
1957. **The application of *Lymantria dispar* L. food specialization as the basis of preventive measures** [in Russian, English summary]. Zool. Zh. 36(3): 408–420.
"Peculiarities of the feeding habits of *L. dispar* may be used as a [basis] of preventive measures by means of plantings restricting the propagation of this pest. Development of preventive measures has to be carried out by means of such a combination of woody plants which provides the greatest possible decrease of the oak damage. Selection of woody plants may proceed in [the] three following directions:

(1) Introduction of species undamaged by *L. dispar*. The moths of *L. dispar* lay their eggs on all the woody plants without selectivity, independently of the feeding habits of their larvae. As the third instar larvae remain on the trees on which they have hatched, they have to succumb, lacking the possibility to feed upon this plant. *Fraxinus,* Ulmaceae trees, wild pear, *Acer tataricum, Caragana arborescens, Sambucus nigra, Euonymus,* [and] *Lonicera* belong to the species undamaged by the above pest under the conditions of the Voronezh district.

(2) Introduction of species attacked by *L. dispar,* but with delayed development compared with the pest. [The] late form of *Quercus robur* belongs to such species in the Voronezh district, as its development is delayed with respect to that of *L. dispar*. Simultaneously, such a measure will check the reproduction of some other leaf-eating pests, for example, *Tortrix viridana* and *Operophthera brumata.*

(3) A number of species, although intensively fed upon by the larvae, bring about metabolism disturbance in the latter and consequently low fecundity of the moths. *Silia parvitolia, Betula alba, Acer platanoides,* and *A. negundo* belong to such species in the steppe aforestation zone."
**All stands: 15; Fecundity: 13; Larvae: 13**

162. Edel'man, N. M., and A. M. Efros.
1962. **The effect of plant growth stimulators on**

**phytophagous insects.** Dokl. Biol. Sci. [English transl. Dokl. Akad. Nauk. SSSR Ser. Biol.] 142: 88–91.

Gypsy moth larvae were reared on oak leaves and artificial media. The leaves and media were treated with five different phytohormones. Larvae fed the treated media had a shorter developmental period, much higher larval weight, and a generally improved physiological condition.

**Oak stands: 15; Generation: 13**

163. Eichhorn, O.
1965. **On some larch pests and their parasites in Japan, Europe, and Canada** [in German, English, and Russian, summaries]. Beitr. Entomol. 15(1–2): 111–126.

"The above paper deals with four pests of larch and their parasites in Europe, Japan, and Canada: *Pristiphora erichsonii* Hartig, *Pachynematus itoi* Okutani, *Diprion nipponicus* Rohwer, and *Lymantria dispar* Linnaeus. The life history and distribution of the two Nematine species, *Pristiphora erichsonii* and *Pachynematus itoi* in Europe and Japan, are more intimately dealt with." The gypsy moth has spread beyond its normal range of distribution in Japan and become a great problem on larch.

**Larvae: 12; Non-oak stands: 15**

164. Emchuk, E. M.
1938. **Catalase dynamics in *Porthetria dispar* and *Dendrolimus pini* during development** [in Ukrainian, English and Russian summaries]. Acad. Sci. Ukr. SSR Rep. Inst. Zool. Biol. 5: 161–180.

This is a report of a study to determine cold resistance during gypsy moth development with parallel analysis of the catalase index. This is an index of the quantity of oxygen/cc given off in 5 min/100 mg of live dry weight. It is a characteristic indication of the state of the organism under definite conditions. The catalase index gradually lowers from the second instar, as does cold resistance. In pupae the index increases, as does cold resistance. Data show that larvae feeding on oak have a higher catalase index than those feeding on apple leaves and that fasting larvae have a higher index than those feeding normally.

**Larvae: 13**

165. Escalera, F. M.
1925. **A new experience in fighting the plague of *Lymantria dispar* in Argelia** [in Spanish]. Verh. III Int. Entomol. Kongr. Zurich 1925 2: 414–416.

166. Escalera. M. M.
1924. **Note on two Coleoptera that attack *Lymantria dispar* and *Tortrix viridana* in El Escorial** [in Spanish]. Bol. R. Soc. Esp. Hist. Nat. 24(5): 273–274.

167. Escalera, M. M.
1925. **Biological note about *Lymantria dispar*** [in Spanish]. Bol. R. Soc. Esp. Hist. Nat. Secc. Biol. 25: 337–340.

Colonies of *Xyladrepa 4-punctato, Calosoma inquisitor,* and *Apanteles* were transported from Spain to North Africa. The *Apanteles* were in cocoons. The plague of *Lymantria* virtually disappeared from La Herreria owing to the great increase of parasites and predators.

**Generation: 3; Instars I–III: 4**

168. Felt, E. P.
1942. **The gypsy moth threat in the United States.** Eastern Plant Board Cir. 1. 16 p.

History of the gypsy moth and the control measures and expenditures to eradicate it. Maintainance of the barrier zone is recommended to prevent spread.

**Review**

169. Fiske, W. F.
1910. **Parasites of the gypsy and brown-tail moths introduced into Massachusetts.** Wright and Potter Printing Co., Boston. 54 p.

Since the natural controls of the gypsy moth were seen to be equal in America and in Europe, except for the lack of effective parasites in America, it was felt that importing parasites from Europe and Japan would cause the decline of the gypsy moth in this country. The early work was completely experimental, since the European literature gave no information on the relative value of the parasites and did not distinguish between parasites and hyperparasites. An important theoretical principle was that a sequence of insects was necessary and

that no one parasite was sufficiently abundant in Europe or Japan to offset the 6-fold rate of increase of the gypsy moth in America. The Japanese race of gypsy moth was larger, stronger, and had a greater fecundity (1/4 to 1/3 more eggs per mass) than the European variety. This indicated greater resistance to control factors, but also more effective controls, as the gypsy moth was not an important pest in Japan. Thirteen species or primary parasites were reared from gypsy moths imported from Japan, seven of them important. All but one was identical or very similar to European parasites. There were at least 22 European parasites, 15 of them important. The greater number of European parasites was probably due to the greater climatic variation in the areas investigated in Europe. The only native American species to be ranked as effective as the imported ones was *Theronia fulvescens,* a relatively ineffective parasite very similar to imported *Theronia* species. The parasites studied were received in sufficient numbers from Europe or Japan to colonize in America. They form a sequence of attack as complete as that in Europe or Japan. A detailed life history is given for each as well as a projected date by which they should become effective in America.

**Eggs: 4; Generation: 12; Larvae: 4; Pupae: 4**

170. Fiske, W. F.
1910. **Superparasitism: an important factor in the natural control of insects.** J. Econ. Entomol. 3: 88–97.

Superparasitism is usually detrimental to the parasites involved. Commonly, the parasites either die before completing development or the resultant adults are stunted, with very low fecundity. In a system in which the parasites are not able to discern a parasitized from a nonparasitized host, superparasitism is prevalent. In such a system, parasitism rarely exceeds 50 percent. This theoretical situation apparently conforms to field observations.

**Generation: 4**

171. Fiske, W.F.
1913. **The gypsy moth as a forest insect, with suggestions as to its control.** U. S. Dep. Agric. Bur. Entomol. Circ. 164, 20 p.

At the time of the first outbreak in the United States, the gypsy moth was thought to be omnivorous. Now it no longer is a field and garden pest, less of a problem in orchards than the American tent caterpillar, and less of a problem in forests than was expected. Amelioration within the Boston area is due to perfection of methods of artificial repression, death or removal of more susceptible trees, importation of parasites and predators, and development of wilt disease.

*Parasites*: Thirty species appear to be important in Europe and Japan, all of which have been introduced into the United States. Of these, one third seem to have become established, which is considered successful. In 1912, 50 percent of gypsy moths were destroyed in the area northwest of Boston.

*Wilt disease*: This is similar to flacherie of silkworm. *Gyrococcus flaccidifex* bacterium is conveyed from generation to generation through the egg. It is not known how it was introduced. Infection will not cause death except in a weakened host, but larvae can pass on disease. The dead caterpillar body becomes black liquid, and germ cells are easily transferred. Death is most likely to occur on the topmost branches of a tree. Gypsy moths with the infection cannot be reared on unfavorable food.

*Stand composition*: Sprouts, and to a lesser extent seedlings, are not so liable to injury as larger trees of the same species. Species in underbrush generally feed from less favorable food sources. Thus, larvae falling from an oak to the ground will find their way back to the oak, whereas when they fall on underbrush they will eat unfamiliar food and be less resistent to disease.

*Comparison with Europe*: In Europe, the invasion of the first decade of the 20th century declined; now the gypsy moth is found in low numbers in virtually all oak forests in Italy and Germany. In apparently all locations where gypsy moth numbers were high, a wilt-type epidemic broke out and numbers decreased. Populations were held at an innocuous level by parasites. In the United States, however, the decline was followed by a phenomenal increase of the straggling remainder. The role played by parasites is obviously less important than had been assumed. Though the increase of the moth was prevented or retarded through parasitism, actual outbreak was checked mainly by disease. Two outbreak areas in southern Italy, where there were varied and abundant parasites but no sign of wilt disease, were observed. Parasites killed 90 percent but the invasion spread back and forth over the area, defoliating a part each year so that trees were defoliated every 2 to 3 years for more than a decade.

**Oak stands: 15; All stands: 15,19; Generation: 2,4,12; Larvae: 5,6,7**

172. Fiske, W.F.
1916. **Insects injurious to vegetation.** Bull. Entomol. Res. 7: 383–389.

The concept that competition among plants may be affected by insects is introduced. An example is offered using the gypsy moth in its relation to pine and oak. These trees are active space competitors. Since the gypsy moth prefers oak to pine, the latter species benefits, as oak is injured to a proportionately greater extent.
**All stands: 20**

173. Fitze, K.
1959. **Establishing gypsy moth foci on the territory of Bosnia and Herzegovina in the course of 1958** [In Serbo-Croatian, English summary]. Zast. Bilja 52/53: 171–173.

To determine localities where the gypsy moth occurs throughout the gradation, even during latency (i.e., its foci), male adults are caught by traps. From the number of males caught, the number of egg clusters is inferred. In 1958, 45 traps were laid and observed from June to August. The results were positive in 76 percent of the cases and negative in 24 percent. It was concluded that the presence of the gypsy moth can be established by means of traps even in cases where egg clusters are almost impossible to find. It was also found that the gypsy moth occupies, even in latency, far wider areas than previously thought. From this it can be deduced that it is autochthonous in areas which it was assumed to have invaded in the course of gradations.
**Adults: 2; Generation: 2**

174. Flanders, S.E.
1963. **Hyperparasitism, a mutualistic phenomenon.** Can. Entomol. 95: 716–720.

"Hyperparasitism is a mortality factor that generally is beneficial to the continuous reproduction of the species involved. The parasites of a primary parasite of a phytophagous insect may exhibit two distinctive types of secondary relations to that insect. These types are defined as follows. Direct secondary parasitism: that type of host-parasite symbiosis where only the primary's parasitized host or the primary itself is attacked. Indirect secondary parasitism: that type of host- parasite symbiosis where the primary's phytophagous host is attacked whether parasitized or not parasitized. The host mortality caused by direct secondary parasitism, this being manifested when the percentage of the primary parasitization of the phytophagous host is minimal.

Hyperparasites are considered beneficial because they stabilize the population fluctuations of the primary parasites. This prevents outbreaks that recur in areas where the phytophagous insects and their regulative primary parasites have been temporarily eliminated. Outbreaks of the phytophagous insect are thus a function of the population lag between reinfestation and parasitization.
**Generation: 4**

175. Forbush, E.H., and C.H. Fernald.
1896. **The gypsy moth: *Porthetria dispar* (Linn.).** Part I. Wright and Potter Printing Co., Boston. 251 p.

Part I by Forbush (251 pages) covers the history of the gypsy moth in America, its increase and distribution, and methods of control, giving special attention to control by birds. The pest was introduced in Medford, Mass., from France by Leopold Trouvelot who was doing experimental crosses with silkworms. Though it escaped in 1868 or 1869, it went unnoticed for 10 years except by Trouvelot. Its early increase was retarded by climate, isolation, birds, and fires. By 1880 it had caused severe damage in the immediate vicinity of Trouvelot's house. Although mechanical control measures were used, it spread to woodlands. Outbreak conditions existed after 20 years in which everything but horse chestnut and grass was eaten. The rate of annual increase was 6 to 7 egg clusters in the second season to 1 cluster in the first. Increase of large colonies was limited only by food; fecundity decreased with food shortage. Larvae deprived of food died or developed prematurely, laying fewer eggs. Larval life span ranged from 6 to 12 weeks. Larvae developed faster and consumed more in warm, dry weather (parasite development sped up also). In 1895 it was unusually warm; larvae developed in 6 to 7 weeks and thus had shorter exposure to vertebrate enemies. Since they developed faster, they ceased feeding earlier and the trees were not stripped throughout the summer. They refoliated in midsummer while females were laying eggs. In one area, there were two generations per year, with larvae leaving the

cluster in September. Cold is believed necessary for embryo development. Isolated colonies do not spread until numbers have increased and all the foliage is destroyed. They will then migrate considerable distances.

The presence of many enemies causes the gypsy moth to scatter. Birds transport larvae by carrying them to their young and dropping them; also, lawvae cling to bird feathers. Occasionally they are transported by the wind or carried along running streams. Egg clusters are laid on leaves on the tree or on the ground, and these may be blown away. Hiding places for larvae include brush heaps, old stone walls, fences overgrown with vines, lumber piles, tin cans, rags and paper. According to Samuel's *Birds of the Northeast* (1980), Trouvelot placed 2000 silkworms on a small oak, and all were eaten by robins and catbirds within a few days. Birds broke through protective netting to devour 95 percent of the silkworms (*Telea polyphemus*) beneath them.

Entomologists generally believe hairy caterpillars are immune to predation by birds, which is perhaps true in Europe. A writer in France in 1833 said that in 20 years of observation he did not see a bird feed gypsy moth larvae to its young. In Russia the cuckoo is said to be the only bird that eats gypsy moth larvae. In several Russian provinces, birds completely abandoned areas where the gypsy moth was numerous. However, in Bavaria, starlings, titmice, and finches gathered in great numbers to feed on an outbreak of closely related nun moth larvae (*Liparis monacha*). In European literature only titmice and cuckoos are mentioned as destroying larvae, while woodpeckers, creepers, and titmice eat eggs. Flocks of titmice and wrens were reported to have cleared eggs in winter from an area in Germany that had been completely defoliated. In the spring, 20 pair of titmice nested there, and larvae noticeably decreased. There was no problem the third season. Information on the most useful birds follows.

*Cuckoo*: A large bird, it prefers large larvae and eats them whole. It is especially valuable in severe local ravages. Some birds will eat pupae if no larvae are available. The adult carries larvae to its young and brings fledglings to the most heavily infested areas when they learn to fly. The yellow-billed cuckoo has been observed to eat 9 to 10 full-grown larvae in 1/2 hour. The black-billed cuckoo does not eat as many, but spends more time beating larvae to kill them or knock off hairs before swallowing them whole. Neither species is very numerous in infested regions, but both are common and are attracted to infestations of gypsy moths. Perhaps because they are large and easily identified, they are considered the most important bird.

The *Baltimore oriole*, a regular consumer of hairy larvae, will take them from under burlap. The adults feed them to the young as a steady diet; often a small part of a larva is eaten. They eat mostly full-grown larvae. The *catbird* feeds on larvae and pupae of all sizes and feeds both to its young when the gypsy moth penetrates into the thicket. It frequents badly infested localities. The *chickadee* skins or tears large larvae to pieces. It stands on larvae and strikes with its bill until they split. It breaks pupae open and eats a small portion of body tissue and juices. It also feeds on adult females and pecks at but does not eat eggs. The *blue jay* feeds larvae and pupae to its young. It finds hidden larvae and pecks at them in bark crevices and also pinches or hammers them to death and drops them. It is common on badly infested trees.

The *chipping sparrow* is primarily grainivorous but was observed killing full-grown larvae in badly infested spots. The *robin* is often seen at the base and on low branches of infested apple and other trees. It is thought by some to be of major importance in killing larvae and pupae. The *red-eyed vireo* is believed to prefer smooth-skinned larvae but often is observed breaking open tents of hairy tent caterpillars. It is known to eat and probably to feed gypsy moths to its young. It usually tears larvae apart but also consumes them whole and feeds them alive to its young. *Crows* feed at and take their young to badly infested areas. They eat larvae, pupae, and adult females, tear dead bark off branches, and penetrate clumps of bushes and rubbish on the ground in search of prey. Under experimental conditions, it was found that crows in captivity rapidly tire of a gypsy moth diet. *Yellow-throated vireos* were observed feeding larvae to young after pecking off the heads.

The *English sparrow* was introduced to Boston in 1868 and drove out species (bluebirds, wrens, house swallows, and martins) that kept the gypsy moth in check during initial years. It was observed that where the English sparrow became numerous, the gypsy moth also increased; bird houses taken over by the sparrow crawled with gypsy moths. Birds may be implicated in the spread of gypsy moths during severe infestations when they will travel far for food for their young, and perhaps

larvae drop or are rejected by the young. Birds are most beneficial at low population densities when they eat caterpillars that are readily available and carry them to the next only when it is nearby. Capturing males generally does no good unless the male fertilizes an isolated population. More species of birds attack moths in orchards than in woodlands.

**Adults: 9; Eggs: 9,10; Fecundity: 2,12; Generation: 2,12; Instars I–III: 9; Instars IV–VI: 9; Larvae: 1,9,10,12; Pupae: 9**

176. Forbush, E. H., and C. H. Fernald.
1896. **The gypsy moth: *Porthetria dispar* (Linn.).** Part II. Wright and Potter Printing Co., Boston. 244 p.

Part II of *The Gypsy Moth* by Fernald (which includes a bibliography) covers the insects' behavior, morphology, and natural enemies as well as insecticides used to combat it. The authors also discuss its prevalence in Europe.

*Situation in Europe:* The gypsy moth disappeared from England by the mid-19th century, perhaps owing to high predation as a result of the darker English foliage. It is widely distributed in Russia but rarely numerous in the same locale for more than 3 years. It eats all species of trees except ash (*Fraxinus excelsior*) and wild pear and is a major problem in fruit trees. In Germany, natural enemies are protected: bats, cuckoos, starlings, crows, titmice, and tree-creepers. The German scientist, Dr. B. Altum, wrote to Fernald: "I have never known a devastation in Germany equal in severity and extent to that in your country. . . An importation of predaceous insects to oppose this destructive *dispar*, e.g. *Calosoma sycophanta,* etc., cannot possibly be of any industrial importance. These work in no noteworthy degree even in our far smaller *dispar* calamities." In Europe the gypsy moth is generally found where there are large areas of cultivated forests, as in Bavaria.

*Natural enemies:* The female is often attacked while laying and is mutilated or eaten by birds and predaceous insects. The large wood ant, *Camponotus pennsylvanicus* (DeG.), will kill a female, gnaw open the abdomen, remove the egg mass, and eat body tissues and fluids, but has not been seen eating eggs. Harvest spiders feed on these eggs. Hymenopterous parasites oviposit in tissue beneath the cuticle, while dipterans lay their eggs on the body surface so they are thrown off when molting. *Theronia melanocephala* (Br.) is the most abundant parasite, attacking pupae and prepupae. The wood pewee has been observed as a predator. *Pimpla pedalis* Cress. breeds from gypsy moth and from tent caterpillar (*Clisiocampa americana*), which pupates 4 weeks earlier.

A list is given (page 377) of hymenopterous parasites in Europe, all of which have cogeneric species in the United States that do not attack the gypsy moth. A large number of *Vespa maculata* L. were observed at a new gypsy moth colony, flying close to the ground, setting around the bases of trees, searching trunks, and occasionally going to the top. They caught male gypsy moths on the wing. *V. consobrina* Sauss. and *V. germanica* Fab. were also observed feeding on the gypsy moth. *Polistes pallipes* St. Farg., a large brown wasp, stung and paralyzed larvae, sucked out fluids, and carried away parts. *Cimbex americana,* the American sawfly, was seen carrying off larvae as was the ant *Fromica subserica.* Among the Coleoptera, several species of *Calosoma* and two species of *Harpalus* and *Platynus limbatus* ate the gypsy moth in the field but not in confinement; *Dermestes lardarius* was found in a mass of pupae. Several Coleoptera larvae were found feeding on egg clusters; *Ptinus brunneus* was the only imago reared from these. In Europe, *C. sycophanta* is predaceous on larvae, *Tiresias serra* (Fab.) on eggs, *Dermestes ater* and *D. lardarius* on both eggs and pupae.

A study found 29 per cent of 5547 gypsy moth larvae bore eggs of dipteran parasites. A list of dipteran parasites in Europe is given, all but one of which, *Achaetoneura fernaldi,* are tachinids of different genera or subgenera of the ones in the U.S.A. *Dasyllis sacrator* Walk. preys on females while they are laying, and *Asilus sericeus* Say captures males on the wing. Arboreal hemipterans prey on larvae, especially in badly infested areas: These include *Podisus cynicus* (Say), *P. serieventris,* and *Monecles insertus.* Spiders prey on all stages but pupal. *Phloeothrips* destroys eggs. Among vertebrate enemies, the common skunk (*Mephitis mephitica* Shaw) feeds on females laying eggs and probably also on pupae in badly infested areas; *Rana silvatica,* the wood frog, preys on females; *Hyla pickeringii,* the tree frog, in one instance preyed on second brood larvae; *Bufo lentiginosus americanus,* the common garden toad, eats many larvae in brushland.

*Life stages:* The female scatters eggs by dropping them, or as a result of disturbance by males at-

tempting to mate while she is laying; thus naked eggs are found at bases of trees or in bark crevices. Of these 85 per cent were fertile on test. Eggs do not lose vitality in cold and wet weather, but temperatures greater than 140°F will destroy them. Mites eat out ragged, irregular openings in eggs, destroying them rapidly, especially in the fall (*Nothrus* near *ovivorus* Pack, *Trombidium bulbipes* Pack). It is possible to have a partial fall hatching in an occasional egg cluster under favorable conditions. The majority of eggs hatch in the warmest part of the day. There is great variation in size and in the number of molts of equal-age larvae. Larvae can float in water for several days without food, can live *in* water 2 to 3 days, can eat water plants (*Nymphaea odorata, Pontederia cordata, Alisma plantago*), and thus can be dispersed along streams. The author does not consider dispersal by wind important; dispersal by man and animal is important in the egg stage. Larvae will eat cotton plants—leaves, stem, boll—voraciously, but are found primarily on orchard trees and elm, on maples and others when they are starving, and more likely on older trees (Appendix A). Smaller larvae tend to eat on lower branches and to move around the tree to shaded places; larger larvae may go to the extreme tips of upper limbs. They return to the same resting and eating places. They cease feeding at daylight, later when the day is cloudy. Small larvae can resist cold but not heat; the reverse is true of older larvae, a finding that correlates with weather conditions during that life stage.

Newly hatched larvae have been observed to spin out silk 4½ feet to 69¼ feet. Larvae in later instars could not be induced to spin, but have been observed spinning in 2nd, 3rd, and 4th molts. When numerous, the larvae collect in masses to spin a cocoon. The percentage pupating on the tree bole increases with abundance. The adult male flies in a zigzag course, most vigorously from 10 a.m. to 3 p.m. on warm days. Females have been observed flying when distrurbed by males. The female is rarely polygamous. Reports of parthenogenisis in Europe: Carlier reports three generations without mating, but the last produced only males. One egg cluster can start a new colony, since males and females emerge simultaneously and will mate.

**Adults: 1,3,9,10,11; All stands: 15; Eggs: 3,12; Generation: 3,9,10,12; Larvae: 1,3,11,13; Prepupae: 4; Pupae: 1,3,4,10; Sex ratio:2**

177. Force, D. C.
1972. **r- and K-strategists in endemic host-parasite communities.** Bull. Entomol. Soc. Am. 18: 135–137.

The parasite with the highest reproductive capacity was found to be the poorest competitor for a host attacked by one or more other parasite species. There is a general inverse relationship between reproductive capacity and competitive ability, suggesting that a parasite complex develops an r-K strategy sequence. General ecological theory explains the large parasite complex by saying that the parasite is very niche-specialized and does not have the potential to adapt to change. The author offers a contrary theory, since numerous introduced pests have been controlled over wide geographical areas by only one or two of their introduced parasites from a much larger endemic complex. In biological control, the parasites that are imported are usually those collected most often from endemic sites. In older disturbances these are likely to be K-strategists, which are most numerous because of competitive selection. These will not be aggressive colonizers. Thus r-strategists are needed, which will be few in number but geographically widespread and more common in new disturbances.

**Generation: 4**

178. Fratzian, A.
1973. **Growth and vitality of oak stands after being eaten by gypsy moths, *Lymantria dispar* L., in Romania** [in German, English summary]. Anz. Schaedlingskd., Pflanz. Umweltschutz 46: 122–125.

Investigations were carried out in Romania in three oak stands (*Quercus pedunculata*) situated in two phytoclimatic regions. Results show that a one year defoliation affects the growth of the trees during the year of defoliation plus the two following years. The total loss of growth is equivalent to 1 year. Two consecutive years of defoliation resulted in a loss of 1.3 years' growth in old trees and 2.2 years' growth in young trees.

**Oak stands: 15,24**

179. Fratzian, A.
1973. **Influences of defoliation caused by *Lymantria dispar* on the growth and vitality of oak stands** [in Romanian, German, summary]. Pages 194–197 *in* Influenta defolierilor produse

de insecte asupra productivitatii padurilor. Editura Ceres, Bucaresti (English transl.).

*Lymantria dispar* is one of the most dangerous forest pests in southeastern Europe. Experiments were conducted on a variety of sites (18 stands infested with *L. dispar* and 11 artificially defoliated) to determine the influence of defoliation on the growth and vitality of oak stands. The following conclusions were drawn: When timber volume decreases, *L. dispar*-caused defoliation decreases. Young stands are more sensitive to infestation than older stands. Neither stand composition nor yield class affects the influence of the infestation on the growth of the stand. A moderately intense infestation (30 to 40 per cent) affects growth only during the attack year. Higher intensity infestations (50 to 80 per cent) influence growth the year following attack as well. Total denudation affects growth for 2 years following defoliation. The total growth loss equals or exceeds a single year's growth. Two successive years of total defoliation cause growth loss during the years of defoliation and during the next two years, with the greatest loss (more than 50 per cent of the annual growth) in the second year of infestation. With these repeated attacks total losses equal 1.2–2 percent of annual growth. Artificially induced defoliation has results equal to insect defoliation. Depending on whether the defoliation is early or late in the season, the greater growth loss is in the year of defoliation or in the following year. Mortality was noticeable only in stands of the weakest class. Different species of oak have different susceptibilities to mortality: 25 percent of *Quercus penduculata* died after 2 successive years of total defoliation. In stands of *Q. frainetti* and *Q. cerris,* mortality is sporadic and generally does not exceed 1 percent. Population increases of *L. dispar* are periodic between 5 and 20 years, depending on geographic region, stand structure, and climatic factors.

**Oak stands: 15,19,20,24,25; Generation: 2,12**

180. French E. W.
1974. **The gypsy moth, *Porthetria dispar* (L.): annotated bibliography 1890–1972.** U.S. Dep. Agric. For. Serv., State and Private For., Northeast Area. 168 p.

Annotated bibliography indexed by author and subject.

**Bibliography**

181. Friend, R. B.
1945. **The gypsy moth in Connecticut.** Trans. Conn. Acad. Arts Sci. 36: 607–629.

Reports covers life cycle and habits, injuriousness, effects of climate, host plants, natural enemies, artificial control measures, and extent of the problem in Connecticut.

**Review**

182. Fukaya, S.
1936. **Parasites of *Lymantria dispar* L.** [in Japanese]. Oyo Dobutsugaku Zasshi 8(6): 332–335.

183. Fukaya, S.
1938. **Effect of temperature and humidity upon the development of *Apanteles liparidis* Bouché and its parasites** [in Japanese]. Oyo Dobutsugaku Zasshi 10(6): 234–244.

184. Furuno, T.
1964. **On the feeding quantity of the gypsy moth (*Lymantria dispar* Linne) and the comphor silk moth (*Dictyoploca japonica* Butler)** [in Japanese, English summary]. Nippon Rin Gakkai-Shi 46(1): 14–19.

Feeding quantity is correlated with amount of frass in individuals feeding on *Quercus acutissime* Carr. The total leaf area eaten at the larval stage was 700–1100cm$^2$ for males and 1100–1800cm$^2$ for females. Insects in the last instar ate 60 to 70 percent of the total. The total number of frass pellets evacuated at the larval stage was about 1500. a straight line logarithmic correlation between feeding quantity and amount of frass was formulated for the gypsy moth.

**Larvae: 1**

185. Furata, K.
1972. **Effect of larval density of *Porthetria dispar* on its population after fasting** [in Japanese]. For. Prot. (Tokyo) 21(5)(242): 92–95.

186. Furuta, K.
1972. **The relationship between population density and mortality in the range of latency of *Lymantria dispar* L.** [in Japanese, English summary]. Nippon Oyo Dobutsu Konchu Gakkai-Shi 16(3): 121–126.

"Eggs and larvae of the gypsy moth, *L. dispar,* were artificially placed on larch and birch trees,

both of which were about 2–2.5 m [in] height, and the environmental resistance of the population, which was kept under a condition of latency, was analyzed. Except [for] death by airborne dispersal in their first instar, most larvae were killed by the predation of birds. The sparrow, *Passer montanus kaibatoi* Munsterjelm, and other birds preyed on the larvae over the third instar. At first the predation was caused independently of larval density, but it soon changed to be density-dependent. Most of the 260 larvae that were placed in the egg stage on 29 larch trees (1 to 40 larvae on each tree), and 2200 larvae that were placed in third instar (20 to 200 on each tree), were preyed upon density-dependently in their third and fourth instars. The 165 larvae of the fifth instar and 125 larvae of the sixth instar having been placed in low density levels (1 to 20 larvae on each tree) were also immediately preyed upon density-dependently. Parasitism by *Apanteles liparidis* was observed; however, as the percentage of third-instar larvae that were parasitized was less than 20 percent, and the parasites killed the fifth-instar larvae, predation by birds, which began in the third instar, was regarded as the regulatory factor of the population."

**Instars I–III: 4,9; Instars IV–VI: 4,9; Larvae 2,9**

187. Furuta, K., and C. Koizumi.
1975. **The mortality factors of experimental populations of *Lymantria dispar* in a larch plantation and natural forest.** Nippon Rin Gakka-Shi 57(12): 432–435.

"The mortality factors of an experimentally established population were observed and analyzed in order to elucidate the control factors which stabilize an insect population during periods of low density. The larvae of *L. dispar* were placed on birch trees (*Betula ermanii* var. *communis*) surrounded by one hectare [of] unstocked space in a natural forest zone in Hokkaido, on larch trees (*Larix leptolipis*) which were planted in a natural forest, and on birch trees (*B. platyphylla*) in a 100-hectare larch plantation. The distance between the *B. ermanii* var. *communis* and *L. leptolepis* stands in the natural forest was about 100 m, and 6 km between the larch plantation and the natural forest. Although more than 90 percent of the larvae on *B. ermanii* var. *communis* or *B. platyphylla* were killed in one month from June to July, only about 65 percent of the larvae were killed on *L. leptolepis* in the natural forest. The larvae on the larch trees in the natural forest were not preyed upon by birds. The differences in mortality among the stands seemed to be caused mainly by bird plundering. The Gordioidea parasite was found on about 20 percent of the larvae on the birch trees, but was not observed in other stands. All the stands were plagued by a species of dipterous parasite which caused high mortality and showed a tendency of density-dependency."

**Generation: 2; Larvae 4,9; Non-oak stands: 15**

188. Furuta, K.
1976. **Studies on the dynamics of the low density populations of gypsy moth and toda-fir aphid: analysis of the environmental resistance factors by artificial host increase method** [in Japanese, English summary]. Bull. Gov. For. Exp. Stn. Kansai 279: 1–85. For. Prot. 4.

This study was done to determine which factors keep an insect species at a low density level. When this level is below the potential for the species, control is by environmental resistance factors. The key factor, which is the environmental factor that dominates changes in density, is not always the factor that controls the insect population at low levels over a period of years. The life table method of evaluating environmental resistance factors is very difficult to develop with species at low population levels. Using instead the artificial host increase method for phytophagous insects, numbers of the insect are artificially released in the egg or larval stage. Mortality factors in each developmental stage are then observed. If two or more groups of different numbers are released simultaneously, it can be seen whether a factor varies in intensity with this difference in numbers. One of the main purposes of these experiments was to confirm whether the factor that varied in intensity with density differences in the subpopulation could control a low density population over the years. It was found that all the important control factors at low density levels were polyphagous predators. These change the cyclical fluctuation of population, if it exists, to one in which a latent population is maintained over a number of years with an occasional outbreak. In the case of the gypsy moth, most released larvae were rapidly preyed upon by birds.

**Generation: 2; Larvae: 9**

189. Galloway, C. W.
1962. **The comparative defoliation of oaks.** J. Elisha Mitchell Sci. Soc. 78(2): 93

The author found that defoliation of 16 species of oak occurred sequentially. Knowing the rate of defoliation of each species makes it possible to identify trees in the field by the condition of the crown.

**Oak stands: 18**

190. Georgijević, E., and V. Vaclav.
1958. **Problem of gypsy moth focuses in Bosnia and Herzegovina** [in Serbo-Croatian, English summary]. Zast. Bilja 41–42: 67–74.

The gypsy moth appears autochthonously in various localities in Yogoslavia that differ considerably from one another. However, the gypsy moth dwells permanently in these areas, and they can be considered its foci. The authors tried to determine which of the 127 localities in Bosnia and Herzegovina in which the gypsy moth appeared in 1957 were its foci. They did this by establishing the presence of *Anastatus disparis* Ruschka, a specific gypsy moth egg parasite with low mobility. Using the hypothesis that *A. disparis* is an indicator of foci, they determined that the gypsy moth can be found permanently in 14 localities. "The reliability of this hypothesis has to be corroborated by further investigations to be carried out in the course of several years."

**Eggs: 4; Generation: 2,12**

191. Georgijević, E., and V. Vaclav.
1958. **Stationary investigations of the dynamism of gypsy moth populations in localities where no control measures against this pest have been taken (1957)**[in Serbo-Croatian, English summary] Zast. Bilja 41/42: 107–122.

Ten localities with 51 test plots of $100m^2$ were studied for 1 year in the territory of Herzegovina to observe gypsy moth developmental stages, movement, and mortality factors. Gypsy moths from each locality were also reared in the laboratory. Analysis of the data obtained from these reared larvae offered a heterogeneous picture of causes of mortality: tachinid parasitism, entomophagous hymenoptera, disease, virus, and *Calosoma sycophanta* predation were major factors in different localities. The graduation lasted an average of 3 years and vanished rapidly. Egg clusters were found under stone piles, in cracks of limestone masses, in sheltered places on the ground and under the earth surface, in interspaces between stones in stone walls, with only a small percentage of the clusters in trees. The principal food plant in investigated areas where a complete browse was observed was *Carpinus orientalis*.

**Eggs: 2; Instars IV–VI: 3,6; Larvae 2,4,6; Non-oak stands 15; Pupae: 2,4,6**

192. Georgijević, E. D. Lutersek, K. Fice, and V. Vaclav.
1959. **Problem of gypsy moth focuses in the PR of Bosnia and Herzegovina.** [in Serbo-Croatian, English summary]. Zast. Bilja 56: 89–94.

Gypsy moth foci in Bosnia and Herzegovina were studied for 3 years beginning in 1957. The gypsy moth appears autochthonously throughout these provinces in all but the central mountain region and plateaus. There are probably genetically different populations in the region connected with specific biotopes with characteristic food plants.

**Eggs: 4; Generation:2**

193. Georgijević, E. Dragutin L., V. Vaclav, and J. Batinica.
1959. **Stationary investigations into the dynamism of gypsy moth populations: localities where no control measures against the gypsy moth have been taken (1959).** [in Serbo-Croatian, English summary]. Zast. Bilja 56: 79–88.

"Dynamics of gypsy moth populations in localities of Herzegovina have been followed since 1957. This was the peak year of gradation, and since that time the population has rapidly dropped in all of the investigated localities (15 with 63 test plots). The rapid decrease of the population, which took place in 1958, was chiefly caused by diseases and natural enemies, which particularly manifested themselves in those localities where the trees had been browsed up in 1957. In 1959 the gypsy moth population reached its maximum in all localities, and the pest was in the period of latency. An exception was Tihaljina, where a treatment was carried out in the immediate neighborhood of the examined locality in 1956. After that a negative reaction of the biocenosis in the form of a rapid numerical decrease of the gypsy moth's natural enemies was observed. It recovered in 1959 and again reduced the increased gypsy moth population."

**Generation: 2,3,4**

194. Gere, G.

1964. **Change of weight, lipid and water content of *Lymantria dispar* L., with special regard to the chemical and energetic changes during insect metamorphosis and imaginal life.** Acta Biol. Hung. 15(2): 139–170.

The results of studies on age, changes in weight, fat, and water content of the gypsy moth (*Lymantria dispar* L.) are presented. "These insects do not feed in the imaginal stage, hence their food and energy supplies are covered by reserve substances stored during the larval stage. The reserve is utilized preponderantly to assure propagation. In the want of food uptake, they decompose the substances of their bodies during life at a rate which calls, from the point of view of production biology, for the coining of a special term, defining these animals as self-decomposers. (The term is undoubtedly applicable to all other holometabolous insects which do not feed in the imaginal stage.) Though this characteristic is valid for both males and females, there is still a certain difference concerning the management of the reserves between individuals of the sexes, just as they differ also in morphological respects. Subsequent to the ceasing of food uptake by the caterpillars, the loss of weight of the males is so great that the weight of a dying moth is only 6.6 percent of the greatest weight of the larva. The decrease in weight is further aggravated by the fact that the imago, after hatching from the pupa, frees itself from all dispensable material, so that its weight will diminish to the smallest possible amount, which again results in its being able to convert a considerably lesser amount of energy covering the work of muscles involved in flight. The males thus utilize their available energy resources almost exclusively for flight in search of mates. The fat content of the male moth is very high, 18.76 percent of the live weight at an age of 33 hours. This supply of fat will be gradually utilized during flight, although a fraction of it will still remain unused at the time of death of the moth. The water content also strongly decreases during the hatching from the pupa and in the first hours of life of the imago. There is no more than 56.5 percent water found in a 24-hour-old male moth. However, the relative water content will diminish but slightly or, in the second half of the period of flight, not at all. This is explicable by the fact that the insect utilizes the water produced in the oxidation of fatty substances. While the males use their food reserves and energy supplies mainly for flight, the females convert them to the production of eggs. The females utilize far less material to cover their metabolic processes than do the males. If no eggs are laid, their weight decreases only by 31.7 percent during the imaginal stage. Also their fat supply, relatively much less than that of the males, decreases insignificantly. An oviposited female, on the other hand, presents quite another picture. The weight of such an insect at its death is generally only 19.2 percent of its weight after its hatching from the pupa. A considerable part of the fatty substances of the insect (about 80 percent of the initial supply) is also transmitted into the eggs. An oviposited female has a higher water content than the eggs; this again proves that the insect transmits the substances of a higher energy content into the eggs."

**Adults: 13; Eggs: 13; Larvae: 13; Pupae: 13**

195. Glaser, R. W., and J .W. Chapman.

1913. **The wilt disease of gipsy moth caterpillars.** J. Econ. Entomol. 6:479–488.

In a paper published in *Science* in 1912, the authors described *Gyrococcus flaccidifex*, a micrococcus they believed to be etiologically connected with the wilt disease. They later found it to be simply a casual intestinal parasite. In an attempt to find the cause of the wilt disease, they perfected a system of filtration through a Berkefeld "Grade N" filter such that no bacteria or polyhedral bodies were present in the filtrate. All that was visible in the filtrate were very minute dancing granules, which were found also in diseased tissue but never in healthy tissue of gypsy moth larvae. Larvae were fed red oak leaves smeared with filtrate material, and those that died were flaccid, disintegrated, and full of polyhedral bodies. Wind is not an important factor in the rapid spread of the disease. Infection in nature occurs when larvae feed on leaves soiled by the juices of dead individuals.

**Larvae: 5,7**

196. Glaser, R. W.

1915. **Wilt of gipsy-moth caterpillars.** J. Agric. Res. 4: 101–128.

There is no record of the wilt disease in the United States prior to 1900. It may have been introduced with parasites imported in 1905, some of which may be important in dispersal of the disease. The first printed record of wilt appeared in USDA

Bulletin 91 by L. O. Howard and W. F. Fiske (1911). Experimental work is described, and a summary of information known about the wilt disease to date is given.
**Larvae: 7**

197. Glaser, R. W.
1918. **A new bacterial disease of gipsy-moth caterpillars.** J. Agric. Res. 13: 515–522.
In 1915 an infectious disease was found in certain cultures of the Japanese gypsy moth. Its causal agent was *Streptococcus disparis*, a new species described in this paper. In nature it is transferred when healthy larvae eat food soiled by feces of infected animals. Thus it enters via the alimentary tract, spreading to all tissues, and causing the most striking changes in muscle tissue. It is not pathogenic to *Bombyx mori* L. (silkworms) or to *Cirphis unipuncta* Haworth (army worms), or to humans, rabbits, or guinea pigs. When introduced in the field it produced an epidemic in Sherborn and North Carver, Mass. and was successful in infecting the American variety of gypsy moth in other locations as well.
**Larvae: 5**

198. Glaser, R. W.
1918. **The polyhedral virus of insects with a theoretical consideration of filterable viruses generally.** Science 48: 301–302.
Experiments done to prove that the wilt disease is caused by an organism and not by an enzyme or toxin involved a large series of passage infections. "Twenty-five gypsy moth caterpillars were infected at a dilution of 1:1000 with material obtained from a caterpillar previously dead of wilt." All 25 died, and one of these was the source for the second passage. Similar third and fourth-passage infections were performed, and all experimental animals succumbed. The period from infection to death was considerably shorter in the last passage. This suggests increasing virulence and strengthens the argument that the disease is caused by parasitic ultramicroscopic organisms.
**Larvae: 7**

199. Glaser, R. W.
1927. **Studies on the polyhedral diseases of insects due to filterable viruses.** Ann. Entomol. Soc. Am. 20: 319–343.
"This study concerns itself primarily with two polyhedral diseases, namely, grasserie of silkworms and wilt of tent caterpillars." Experiments show that these diseases and the gypsy moth wilt, which are similar histopathologically, are caused by distinct, specific viruses.
**Larvae: 7**

200. Gogola, E.
1968. **Width of the head capsule in relation to the sex and number of instars in the larval development of gypsy moths, *Lymantria dispar* L.** [in Czechoslovakian, Russian and German summary]. Biologia Bratislava 23(8): 610–616.

201. Goldschmidt, R.
1934. **Lymantria.** Bibliogr. Genet. 11: 1–186.
This is an extensive work on the genetics of the gypsy moth. Particular attention is paid to geographical races and to the results of crosses between them, such as intersexuality, the phenomenon of beginning development as one sex and, without a change in chromosomes, finishing as the other sex. In *Lymantria,* female factors are inherited maternally within cytoplasm and male factors are determined by the X chromosome. Sex is determined by a quantitative relation between male and female factors. Over the Eurasian continent races are not very distinct, although some differences are noted. Generally the species works "toward a relative constancy of forms within an area," since means of dispersal are limited. When there is dispersal to a new climatic regime, success of the species depends on its ability to adapt and synchronize its life cycle with the seasonal cycle.
The original home of the genus *Lymantria* was Southeast Asia, and only a few of the species spread to the Palearctic. The northern limit of the gypsy moth now seems to be the isotherm of Stockholm, and owing to human transport, the southern limit may be as far south as North Africa. The smallest forms in both sexes are from southern Europe and Massachusetts. Medium sizes are in northern Europe and Turkestan as well as in Hokkaido, North Hondo and Korea; in northeastern and southwestern Japan the gypsy moth is large. Body size and rate of development are not correlated and egg size shows no racial difference.
Four main racial types have been distinguished based on larval coloration: (1) dark—Europe, Russia, Turkestan, Mediterranean, North China (Tsingtao), and Manchuria; (2) light—southwest Japan, extending into Korea; (3) intermediate—

northeast Japan; and (4) bright markings—Hokkaido. Wing and body color are determined simultaneously, as seems to be the case in all Lepidoptera. The geographical variations of adults are: (1) European forms—distinguishable from Japanese forms, but similar grayish brown males are found in Korea, China, and Manchuria. In southern Europe and Turkestan, males may also be yellow- brown. Females are all whitish with clear zigzag bands. (2) Island of Hokkaido— males, vary, but most commonly are whitewinged, except for the base and edge of the wings. (3) Japan—female wings are gray. The color of the abdominal hair used to cover the eggs is dark in northern European types and light in southern European, Massachusetts, and Turkestan forms. There is the same north-south difference in Japanese and Korean races.

"The formation of geographical races or subspecies is not a first step toward speciation but leads only to diversification within the limits of the species. This diversification is mainly of an adaptive nature, adapting the species to different special environmental conditions within the area to which it is adapted as a species. This adaptation proceeds by mutation and immigration into a fitting environment, according to the principle of preadaptation."

**Adults: 1,12; Generation: 1,12,13; Larvae:13**

202. Gonzalez de Regueral, A.
1946. **Combating the gypsy moth** [in Spanish]. Montes 2(8): 132–140.

203. Gould, W. P.
1971. **Making the gypsy moth go away and stay away by modifying the forest environment to make it less susceptible.** R. I. Resour. 17: 1–4.

The author proposes that the best method for removing the threat of gypsy moth defoliation is through silvicultural practices. This entails removing species of the food class A type. In most instances this results in a white pine stand.

**All stands: 19,20**

204. Granett, J.
1974. **Estimation of male mating potential of gypsy moths with disparlure-baited traps.** Environ. Entomol. 3: 383–385.

Estimation of gypsy moth, *Porthetria dispar* (L.) male mating potential has been made using box-type disparlure-baited traps. This potential, estimated by the reciprocal of the time elapsed before virgin females mated during the natural gypsy moth flight, was proportional to 22-h trap catches. Seasonal trap catches tended to be proportional to population as estimated by counts of pupae under burlap bands, with estimates adjusted for numbers of oak trees in 0.1-ha plots. Trap catches were highest when traps were adjacent to large trees and 1.5 m or less above the ground." Male moths frequently fly up and down beside large tree trunks in search of females. It may be possible to use pupal counts as an advance indication of adult population trends and male mating potential.

**Adults: 1; Pupae: 2**

205. Gravatt, G. F., and G. B. Posey.
1918. **Gipsy moth larvae as agents in the dissemination of the white-pine blister-rust.** J. Agric. Res. 12: 459–462.

Gypsy moth larvae feed on the peridermium stage of *Cronartium ribicola,* the white-pine blister-rust, and carry thousands of aeciospores on their bodies. They also feed on the leaves of *Ribes* spp. In some cases the only *Ribes* leaves infected with *C. ribicola* are those showing gypsy moth injury. Germination tests made of spores on the bodies of larvae collected on cankers showed approximately the same percentage germination as spores collected directly from the cankers, but tests of spores in frass pellets showed very poor germination. Because the gypsy moth can be carried as far as 20 miles in the wind, can transport viable spores, and feeds on both white pine and *Ribes,* the larvae are certainly a factor in spreading blister-rust.

**Instars I–III: 1; Non-oak stands: 15**

206. Grigorova, R.
1964. **Two strains of *Bacillus thuringiensis* Berliner isolated from the larvae of gypsy moth, *Lymantria dispar*** [in French, English summary]. Pages 179–191 in Colloq. Int. Pathol. Insect. Lotte Microbiol., Paris, 1962.

Two strains of spore-forming and crystal-forming bacteria were isolated from the larvae of *Lymantria dispar:* one in 1959 in the field and another in 1962 in the laboratory. Both strains were serologically and physiologically investigated. The field-isolated strain was found to be *Bacillus thuringiensis* serotype I *berliner,* and the laboratory strain was identified as *B. thuringiensis*

serotype IV biotype 6 *dendrolimus*. The field-isolated strain was more virulent for *L. dispar* larvae then the *dendrolimus* strain, even at one fourth the concentration.
**Larvae: 5**

207. Grisson, P.
1955. **Abrupt regression of *Lymantria dispar* L. because of the predatory activity of *Calosoma sycophanta* in the Corsican cork oaks** [in French.] Rev. Zool. Agric. Appl. 54(4-6): 51-56.

In the southeastern part of Corsica, a gypsy moth outbreak which peaked in 1952-53 almost completely defoliated the cork oaks for three consecutive seasons. In 1954 *Calosoma sycophanta* L. was the main control agent of gypsy moth larvae in Languedoc, Maures, and Corsica. Local estimates placed the number of beetles per tree at 100.
**Generation: 2; Larvae: 1,3; Pupae: 3**

208. Gyorfi, J.
1941. **Secondarily detrimental insects after damage done by *Lymantria dispar*** [in Hungarian; German, French, and English summaries]. Erdezeti Lapok 80(3): 120-123.

The following list of species is given. Coleoptera: Buprestidae—*Dicerca alni* Fisch., *Lampra rutilans* F., *Chrysobothris affinis* F., *Coraebus bifasciatus* 01., *Agrilus biguttatus* F., *A. viridis* L., *A. angustatus* I11. Eucnemidae—*Melasis buprestoides* L. Cerambycidae—*Aegasoma scrabricorne* Scop., *Rhagium mordax* Deg., *Cerambyx scopolii* Füssl., *Rhopalopus insubricus* Germ., *Pyrrhidium sanguineum* L., *Callidium variabile* L., *Xylotrechus arvicola* Oliv., *Clytus arietis* L., *C. tropicus* Panz., *Plagionotus arcuatus* L., *P. detritus* L., *Liopus nebulosus* L., *Haplocnemia nebulosa* F., *Saperda scalaris* L. Curculionidae—*Cryptorrhynchus lapathi* L., *Gasterocercus depressiorostris* F. Ipidae—*Xyleborus monographus* F., *X. dryographus* Rtzb., *Anisandrus dispar* F. Platypodidae—*Platypus cylindrus* F. Hymenoptera: Siricidae—*Xiphydria longicollis* Geoffr., *X. prolongata* Geoffr. Lepidoptera: Cossidae—*Zeuzera pyrina* L. Sesiidae—*Trochilium spheciforme* Gong. This list represents the results of the author's investigations carried out on material gathered in Hungarian woods attacked by *Lymantria*.
**All stands: 16, 17**

209. Gyorfi, J.
1943-1944. **Ecological investigations on the life of Hymenoptera** [in Hungarian and German]. Erdeszeti Kiserl. 45(1-4): 1-68.

210. Gyorfi, J.
1945. **Observations on the nutrition of ichneumon fly imagos** [in Hungarian, German, and French summaries]. Erdeszeti Kiserl. 45:87-114.

211. Gyorfi, J.
1961. **The parasites of *Lymantria dispar* L. according to newest researches** [in Hungarian, English and German summaries]. Erdeszeti Kut. 57 (1-3): 275-285.

"In Hungary the gypsy moth (*Lymantria dispar* L.) damages mainly the pure stands of Turkey and pedunculate oak (*Quercus cerris* L. and *Qu. robur* L.) growing on the. . .mountains Vért- Pilis-Cserhát-Mátra as well as in the eastern part of the county Somogy and in the western part of the counties Baranya and Tolna. By eating the leaves, the caterpillars of this moth cause losses primarily in increment, and if the attack continues for a rather long time, the weakened trees and woodlots may be entirely destroyed by secondarily injurious insects and fungi. The gypsy moth is polyphagous to such a high degree that it feeds—with the exception of wild pear (*Pyrus pyraster* L.), ash (*Fraxinus* sp.), privet (*Ligustrum vulgare* L.) and lilac (*Syringa vulgaris* L.)—sometimes attacks even these species. However, turkey and pedunculate oak are the principal host plants of this moth. It propagates in stands of these two species and seeks other plants only after becoming too numerous." It flourishes if the equilibrium of the biotic community is disrupted, as when parasites that previously held it in check die out. "The principal species of these controlling parasites are as follows: the beetle *Trombidium holosericeum* L.; the real ichneumon flies *Protichneumon disparis* Poda, *Theronia atalantae* Poda, and *Hyposoter disparis* Vieill.; the braconids *Apanteles fulvipes* Hal., *A. liparidis* Bouché, *A. porthetriae* Muesb., *A. melanoscellus* Rtzb., *A. lacteicolor* Vier., and *Microgaster tibialis* Nees.; the chalcids *Brachymeria intermedia* Nees and *Anastatus disparis* Rusch.; as well as the species *Compsilura concinnata* Meig., *Lydella nigripes* Fall., *Parasetigena segregata* Rond., *Sturmia scutellata* R.D., *Carcelia excisa* Fall., *Tachina larvarum* L., and

*Trustica* Meig. belonging to the Tachininae. All these parasites are described." Their primary and secondary hosts, as well as the plants preferred most by ichneumon flies, are enumerated. "From the data, the conclusion could be drawn that the propagation of the gypsy moth may be controlled best by mixed forests planted on good soil and having a rich undergrowth."

**Oak stands: 15, 16; All stands: 15; Eggs: 4; Larvae: 4; Pupae: 4**

212. Hackett, K. J.
1971. **Parasites associated with various densities of the gypsy moth, *Porthetria dispar*, in Yugoslavia.** M. S. thesis. Rutgers Univ., New Brunswick, N. J.

This is a survey of parasites associated with various population densities of gypsy moth larvae in the Danube River Valley, Yugoslavia. In Bagremera, a woodlot with grassy underbrush where density was highest, a crow infestation fed on gypsy moth adults. In Celarevo, where there has never been a recorded outbreak, the low density was perhaps due to periodic flooding which drowns larvae, prevents tree-to-tree migration, and kills eggs if the water is at about room temperature for one month. There was no statistical difference in percentage of total parasitism between the six areas studied, but classes of parasites differed.

*Apanteles* spp. were more prevalent in low-density areas, except for *A. solitarius* which has up to three generations per year and can therefore build up very rapidly in high-density gypsy moth populations. *A. prothetriae* has one generation per year on gypsy moth, and its buildup is dependent on alternate overwintering hosts. *A. ocneriae* is found in small numbers in high- and low-density areas' *A. liparidis* is prevalent in stabilized areas only; however, both are gregarious. Some investigations believe *A. solitarius* and *A. melanoscelus* are the same species since they interbreed in the laboratory, but their life cycles differ: *A. Solitarius* has two broods emerging in spring and overwinters in first instar, or as prepupae within cocoon, or as female at tree base; *A. melanoscelus* overwinters as diapausing larvae and has one brood emergence in spring.

Their host preferences differ: *A. solitarius* favors satin moth, whose presence may have drawn this parasite to Bagremera. *Apanteles* spp. respond to gypsy moth density in two ways: In stabilized areas a greater species diversity accounts for a higher incidence of parasitism; in high-density areas multibrood species predominate. *Hyposoter* spp. (Ichneumonidae) abundance is not related to density factors but to environmental conditions. It overwinters on ground and therefore is killed in Celarevo where there is flooding. It produces 1200 eggs per female per year. Hyperparasitism mortality is high in Yugoslavia in the overwintering cocoon stage.

Tachnids: *Carcelia gnava* Meigen is multibrooded, with perhaps only one generation on gypsy moth, since it would not breed in the laboratory. It is probably of minor importance. *Compsilura* sp. differs from *C. concinnata* in that environmental tolerences are narrower and sex ratio of female to male was 3:1 instead of even. Both are abundant in areas of low to medium host density, since they follow population trends of alternate and overwintering hosts which are prevalent in gypsy moth latency. *Exorista larvarum* L. emerges from larvae and pupae; it is the most abundant parasite in high-density areas. The female lays up to 2000 eggs, attacks avidly, and will develop in diseased larvae, but needs alternate hosts. *Sturmia scutellata* may be beneficial in low-density areas owing to its superior searching abilities. Since it will lay up to 5000 eggs, it is also valuable in high host density areas. It emerges mostly from pupae. It is especially important the first year after culmination, when the predominant parasite is determined by the life stage of the moth when the collapse occurs. Parasites emerging from that stage predominate the following year. An unidentified *Sturmia* sp. was also found; it overwinters as a larva rather than a pupa. Previous importations of parasites (1905–1914, 1922–1933) were from areas of high density from the first year after culmination; thus high-density parasites predominate.

**Adults: 9; Eggs; 12 Larvae: 2, 4, 12**

213. Hadžistević, D., and H. Hadžihalilović.
1959. **Gypsy moth gradations on the territory of PR Bosnia and Herzegovina** [in Serbo-Croation, English summary]. Zast. Bilja 52–53: 153–159.

"The authors give a survey of gypsy moth gradations on the territory of the PR of Bosnia and Herzegovina, based on the information concerning these gradations already published in the professional literature and various other publications. The arranged data show that this pest appeared 10

times in overpopulation in the course of the last 76 years (in the period from 1880 to 1956)."
**Generation: 2**

214. Hall, R. C.
1935. **Cape Cod pitch pine: its resistance to gipsy moth defoliation and its advantages as a forest tree.** J. For. 33: 169–172.
Pitch pine is the tree species of the forest community of Cape Cod least affected by the gypsy moth. It appears to be the least preferred food species present. During severe outbreaks the older needles are eaten, but never the new growth. The turnover rate of pitch pine foliage is about 2 years. This type of defoliation, therefore, has little effect on tree condition.
**Non-oak stands: 15, 19, 26**

215. Hanson, J. B., and J. M. Reid.
1972. **Evaluation of larval and pupal parasitism of the gypsy moth in northeastern Pennsylvania.** U. S. Dep. Agric. For. Serv., State and Private For., Northeast Area. 7p.
Larvae were collected and maintained in the laboratory. Pupae were marked in the field. Percent parasitism was calculated for the larvae and pupae as well as for each parasite. Virus accounted for 44 percent of larval mortality. *Apanteles melanoscelus* and *Blepharipa scutellata* accounted for 90 percent of the deaths due to parasitism. Virus killed 61 percent of the pupae, with *B. scutellata* accounting for 91 percent of pupal mortality due to parasitism.
**Larvae: 4, 7; Pupae: 4, 7**

216. Hanson, J. B., and R. C. Reardon.
1973. **Selected references pertaining to gypsy moth parasites and invertebrate predators.** U. S. Dep. Agric. For. Serv., State and Private For., Northeast Area. 26p.
Selective bibliography on gypsy moth parasites and invertebrate predators.
**Bibliography**

217. Harding, K. C.
1930. **A change in nesting habits of the wood pewee.** Bird Banding 1(3): 144.
In 1924 some wood peewees (*Myiochanes virens*) built their nests 50 feet above the ground in oak trees near Holderness, N. H. During the next 2 years, gypsy moths stripped the oaks at about the time the young wood peewees hatched. The fledglings perished either from exposure to sun and rain or from predation by crows or hawks. The wood peewees changed their nesting habits and in 1927 began to built their nests in beech and maple saplings, the leaves of which were not eaten by the gypsy moth.
**Larvae: 9**

218. Hartmann, G. C., and S. S. Wasti.
1974. **Infection of the gypsy moth, *Porthetria dispar*, with the entomogenous fungus *Conidiobolus coronatus*.** Entomophaga 19: 353–360.
"Fourth-instar larvae of the gypsy moth, *Porthetria dispar* (L.) were infected with the fungus *Conidiobolus coronatus* (Cost.) Batko using the spore-shower techniques for varying periods of time. Larvae treated for more than 20 minutes showed 100 percent mortality Virulence of the pathogen was increased by inoculating larvae of the wax moth *Galleria mellonella* (L.) three times in succession. Typical symptoms of the infection were lightening of color, flaccidity, shrinking, and finally desiccation of the larvae. Observations on the histopathology of infected larvae showed penetration of the integument by hyphae within 22 hours after inoculation, and at 34 hours postinoculation the hemocoelom, head, nervous system, and muscles were completely infected. A localized mycelial growth in the digestive system resulted, probably caused by the ingestion of spores, but penetration of the gut wall was not recorded."
**Instars IV–VI: 8**

219. Heil, K. H.
1937. **An outbreak of the gypsy moth on the Rhine** [in German]. Nachr. Schadl- Bekaempf. 12(4): 218–225.

220. Henze, O.
1934. **On the effect of air in motion on the development of Lepidoptera** [in German]. Z. Angew. Entomol. 21(3): 385–405.

221. Hinckley, A. D.
1970. **Male gypsy moth dispersal on Long Island (Lepidoptera: Lymantriidae).** J. N. Y. Entomol. Soc. 78: 170–174.
"During July 1969, virgin female gypsy moths were used as decoys to sample male gypsy moth populations on Long Island. Although most common near an area in which larvae had completely defoliated tall oaks, male moths dispersed into

areas where infestations were sparse or nil. Increases in the average size of male moths were noted at several trapping sites during the sampling period, this change being attributable to the early emergence of small moths in severely defoliated areas." Males are by no means confined to zones where their chances of encountering virgin female are high. Intervals between catches of males seemed to be directly correlated with the distance from the main infestation site. Smaller moths reflected earlier emergence and seemed to have been subjected to malnutrition during their larval stages in the defoliated foci.
**Adults: 1, 2; Larvae: 13**

222. Hofmann, C.
1933. **The influence of starvation and restricted space on the growth and reproduction of Lepidoptera** [in German]. Z. Angew. Entomol. 20(1): 51–84.

223. Holbrook, R. F., M. Beroza, and E. D. Burgess.
1960. **Gypsy moth (*Porthetria dispar*) detection with the natural female sex lure.** J. Econ. Entomol. 53:751–756.
The time of flight of the male moth "depends greatly on the weather, especially on the temperature. The more northerly or cooler areas have later flights. However, the time of flight is not uniform even in the same general vicinity; flights in cooler areas are delayed . . . few males are trapped on rainy days or when the temperature is below 70°F. Usually the main flight takes place over a 10- to 14-day period; however, continued cool weather during the summer of 1956 stretched this flight period to about a month."
**Adults: 1, 12**

224. Houston, D. R.
1973. **Diebacks and declines: diseases initiated by stress, including defoliation.** Proc. Int. Shade Tree Conf. 49: 73–76.
The gypsy moth, along with leaf rollers, leaf tiers, and the elm spanworm, has initiated oak decline over large areas of the Northeast, Mid- Atlantic, and Southeast. Defoliation causes a biochemical change in the wood tissue: starch reserves decline, and sugars that are normally present in small amounts (glucose and fructose) increase. Severe drought also brings about these changes. These conditions render the tree susceptible to invasion by *Armillaria mellea,* which readily metabolizes gluclose and fructose, but utilizes sucrose (the sugar that normally predominates) poorly. Other biochemical changes are caused by defoliation, such as changes in the concentration of certain amino acids in roots and in the phenolic compounds of bark, but these have not yet been correlated with activities of secondary organisms. In areas frequently defoliated y the gypsy moth, trees may not be as badly affected by severe defoliation as trees in sites disturbed infrequently. This is because of the relative energy demands of small, slow-growing trees versus those of large, rapidly growing trees.
**Oak stands: 15, 16, 18, 23, 25**

225. Howard. L. O.
1905. **The gypsy and brown-tail moths and their European parasites.** U. S. Dep. Agric., Yearb. Agric. 1905: 123–138.
This is an article for lay persons, reviewing the life histories of the gypsy moth and brown-tail moth and methods for controlling them.
**Generation: 1**

226. Howard, L. O.
1907. **The gipsy moth and how to control it.** U. S. Dep. Agric. Farmer's Bull. 275.
Review of introduction of the gypsy moth to the United States, its distribution as of 1907, its life history, and control measures.
**Generation: 1,2**

227. Howard, L. O.
1910. **Technical results from the gipsy moth parasite laboratory. I. Parasites reared or supposed to have been reared from the eggs of the gipsy moth.** U. S. Dep. Agric. Tech. Ser. 19.
No native American parasites have ever been reared from the eggs of the gypsy moth, probably owing to the character of the egg mass. It is compact and is covered by the scales of the parent, possibly to disguise its character from potential parasites for many generations. Only two of the parasites reared from abroad seem to be of primary importance: *Anastatus bifasciatus* Fonsc. and *Schedius kuvanae* Howard. The latter came from Japan, and the former has been reared in Japan, the Crimea, and Hungary.
**Eggs: 4,12**

228. Howard, L. O., and W. F. Fiske.
1911. **The importation into the United States of the parasites of the gipsy moth and the brown-tail moth: a report of progress with some consideration of previous and concurrent efforts of this kind.** U. S. Dep. Agric. Bur. Entomol. Bull. 91.

This is a classic history of parasite introduction efforts, including a chapter on early work done to control other insect pests and a chapter on gypsy moth parasitism in Japan, Russia, and Europe. Details are given on a number of the introduced parasites. Disease is discussed as a factor in gypsy moth control, particularly as related to the need for continuing parasite importations. Since first noted by Fiske in 1907, the wilt disease became important as an efficient means of control. Observations in parts of Russia where parasite control was inefficient and observations on diseases of other large lepidopteran larvae indicate, however, that disease alone does not exert a controlling influence until the insect has already become a pest. Thus it does not diminish the need for parasite introduction.

**Eggs: 4,12; Larvae: 4,7,12; Pupae: 4,12**

229. Howard, L. O.
1916. **The practical use of the insect enemies of injurious insects.** *from* U. S. Dep. Agric., Yearb. Agric.

This is a review of attempts to import parasites. In ordinary years in their native homes, parasites and native enemies destroy 90 percent of hatched gypsy moths.

**Eggs: 4**

230. Howard, L. O.
1922. **A sideline in the importation of insect parasites of injurious insects from one country to another.** Proc. Nat. Acad. Sci. U.S.A. 8: 133–139.

Although parasites and predators have been imported to control specific pests, usually those introduced from abroad, they often also act to control other native pests.

**Generation: 4**

231. Hoy, M. A.
1975. **Hybridization of strains of the gypsy moth parasite, *Apanteles melanoscelus*, and its influence upon diapause.** Ann. Entomol. Soc. Am. 68: 261–264.

"Colonies of *Apanteles melanoscelus* (Ratzeburg) from France, Yugoslavia, and Connnecticut were crossed, and photoresponse curves were obtained for the three strains and their hybrids under laboratory and outdoor insectary conditions. Photoperiodic responses of the Connecticut strain were different from those of the French and Yugoslavian parasites and their hybrid. The triple hybrid was different from the French, Yugoslavian, and Connecticut strains in its diapause characteristics. The laboratory-determined critical photophases at 24°C were: Connecticut, 16–17 h; French-Yugoslavian-Connecticut hybrid, 15 h; French, Yugoslavian, and French-Yugoslavian hybrid, 12.5–13.5 h. Under outdoor insectary conditions, the average percentage entering diapause for each strain was: Connecticut, 96 percent; a newly collected French colony, 99 percent; a laboratory French colony, 8 percent; Yugoslavian, 8 percent; French-Yugoslavian hybrid, 7 percent; and French-Yugoslavian-Connecticut hybrid, 30 percent."

**Larvae: 4**

232. Jacentkovský, D.
1935. **The tachinid enemies of *Liparis dispar* L.** (in Czechoslovakian). Lesn. Pr. 14(9–10): 451–457.

233. Jahn, E., and A. Sinreich.
1957. **Observations on the occurrence of the gypsy moth (*Lymantria dispar* L.), the brown-tailed moth (*Euproctis chrysorrhoea* L.), and the green oak leaf rollers (*Tortrix viridana* L.) in lower Austria and in Burgenland in the years 1952–1956** [in German]. Anz. Schaedlingskd. 30(9): 139–146.

234. Janković, L.
1954. **Some observations on the vertical expansion of the gypsy moth** [in Serbo-Croatian, English summary]. Zast. Bilja 23: 102–103.

"After giving several observations on the vertical expansion of the gypsy moth, the author concludes that this pest, from the oecological point of view, gets easily accustomed to different climatic conditions, causing the same damage in its new surroundings as it did in the most suitable places to its development. Comparing the gypsy moth females coming from various altitudes proved that there were great differences in their respective sizes. The latest appearance of the gypsy moth

pupa, so far noted in . . . [Yugoslavia], was about the middle of September in the forest, and the female imago that developed from this pupa in the laboratory was observed in October."
**Generation: 12**

235. Janković, L.
1956. **Some observations on the ecology of the gypsy moth (*Lymantria dispar* L.) in hill and mountain forests in Yugoslavia** [in Serbo-Croatian, English summary]. Rec. Trav. Inst. Biol. Beogr. 7(8): 2–20.

At higher altitudes the density of gypsy moth is kept down by regulatory factors (climate). Biotic factors (parasites and predators) are less important because "late spring frosts, which are common at the altitude [of] 1300 m, regularly destroy the vegetation so that the caterpillars, being without food, have a higher mortality. High numbers of rainy and snowy days hinder the normal feeding of caterpillars in those regions, prolonging . . . [the development of the larvae.] The fecundity of the gypsy moth is also influenced by such conditions." The upper limit reached by the gypsy moth in Yugoslavia is 1550 m above sea level. At this altitude they do not have optimal living conditions, but they can exist normally for a few years. From this it is concluded that "the gypsy moth has a wide ecological valence for climatic factors and also that it is adaptable to the wide amplitudes of ecological factors."
**Fecundity: 12; Generation: 12; Larvae: 12**

236. Janković, L.
1958. **Comparative oecological investigations of the gypsy moth in hilly and mountainous biotopes on the Mokra Gora (Jovin Grob) and Kopaonik in the period from 1954 to 1957** [in Serbo-Croatian, English summary]. Zast. Bilja 41/42: 81–87.

The gradation of the gypsy moth differs between highland and lowland regions. A characteristic feature of the highlands is that "gypsy moth clusters are hardly perceptible in them, regardless of the degree of gradation." Most clusters are deposited "in sheltered places (in heaps of twigs, piles of stones, under peeled-off bark, under superficial roots, and on the ground)" rather than on tree trunks. The gradation curve shows a rather gradual increase as well as decrease in the population, as opposed to the gradation curve in lowland forests. In 1957 there was a 4-month difference between the first observed emergence of a male moth in the lowlands and in the mountain forest of Kopaonik at 1550 m. In the mountains, pupation is under stones and pupae are preyed upon by a species of *Carabus*. In the lowlands, *Carabus* is not a predator because pupation is in the trees, and these beetles do not climb trees. In the mountains there is a comparatively high percentage of unfertilized eggs (27 percent), indicating protogyny. The rainy and snowy days in the mountains hinder normal larval feeding, prolong the duration of development, and influence fertility. At the highest altitude, beech is the principal tree species. These factors taken together control the population of gypsy moth at higher altitudes.
**Eggs: 2; Fecundity: 12; Generation: 2,12; Instars I–III: 12; Larvae: 3; Non-oak: stands 15; Prepupae: 3; Pupae: 3**

237. Janković, L.
1958. **Comparative oecological investigations of the gypsy moth in the enclosure of Trstena (near Mladenovac)** [in Serbo-Croatian, English summary]. Zast. Bilja 41/42: 139–142.

In a study lasting from 1947 to 1957, two gradations and the period of latency between them were observed in a lowland forest (130 m) representative of the terrain of Sumadija. The first gradation began in 1946 and culminated in 1949 when 9,452 egg clusters/ha were laid. The population decreased rapidly by the following year owing to tachinid parasitization of larvae (86 percent). The second gradation (1953–1957) was represented by an atypical curve with a slower-than-average population increase and a lower-than-average number of larvae in the progradation. The average number of eggs decreased with the progress of the gradation. The average number of eggs in a cluster was almost the same in the culminant years of both gradations.
**Eggs: 2; Generation: 2; Larvae: 2,4**

238. Janković, L.
1958. **A contribution to the knowledge of gypsy moth foster plants in the nature in the course of the last gradation (1953–1957)** [in Serbo-Croatian, English summary]. Zast. Bilja 49/50: 35–39.

As the 1953–1957 gradation progressed, the number of gypsy moth host plants increased. In the first year the larvae ate only the optimal food: oak in low-lying biotopes, willow and poplar in

marshy regions, oak and beech in the hills, and beech in the mountains. In a pure oak stand in culmination the larvae browsed first in the trees, then passed to the shrubs, and finally to the ground cover. During the course of the gradation, 276 host plants were noted. Complete defoliation was observed on 33 species of forest trees, 7 fruit trees, 19 shrubs, 19 cabbage-like plants, 25 weeds, and 3 species of cultured plants.

**Oak stands: 15; All stands: 15; Larvae: 2**

239. Janković, L.

1958. **Dynamism of the gypsy moth population of Jakovački Ključ** [in Serbo-Croatian, English summary]. Zast. Bilja 41/42: 35–48.

Nineteen 1000m$^2$ test plots, representing a variety of habitats (old forest, middle-aged forest, young forest, and thicket), were studied at Jakovački Ključ, Serbia, in 1957 when the gypsy moth was in retrogradation. Observations on egg clusters included the number per square hectare (304 old forest, 365 middle-aged forest, 207.4 young forest, 43.4 thicket); number per tree (0.6 old forest, 0.3 middle-aged forest, 0.03 young forest, 0.003 thicket); height at which clusters are deposited (40.7 percent up to 50 cm, 97.3 percent up to 4 m); size of cluster; percentage of trees infested with clusters (5.4 percent; average number of eggs (175.5 in thicket, 204.2 in young forest, 202.2 in middle-aged forest, and 204.5 for whole biotope); percentage of unfertilized eggs (22.5 percent), and the percentage of clusters deposited in trees (90.3 percent) and on shoots (9.7 percent), a ratio that changes during the gradation. Observations were also made on the duration of the life stages, larval behavior, number of larvae per tree, sex ratio (6:1 in favor of males), fertility (94.1 percent of fecundity), and percent parasitization (80 to 100 percent).

**Eggs: 2; Fecundity: 2; Generation: 2,4,12; Sex ratio: 2**

240. Janković, L.

1958. **Foster plants of the gypsy moth (*Lymantria dispar* L.) in the open in the course of a single gradation** [transl. from Serbo-Croatian]. Rec. Trav. Inst. Biol. Beogr. 2(2): 1–15.

Number of food species and intensity of defoliation by the gypsy moth "depend on the stage of the gradation, floral structure of the biotope, and geographical position." In the progradation, *Quercus* is the principal food species. In the pre-eruption, *Quercus, Carpinus, Ulmus, Populus,* and *Salix* are important. Food sources in the eruptional stages include all forest and fruit trees, shrubs, herbaceous plants, weeds, industrial, cultural, and fodder plants, fruits, and vegetables. A total of two hundred eight plant species recorded as food sources of the gypsy moth includes 60 species of forest trees, 16 species of fruit trees, 33 species of shrubs, and 99 species of herbaceous, industrial, and fodder plants. The vast majority of the plants are defoliated only during an outbreak. Knowledge of all food plant species may help in predicting the effect on the gypsy moth population, if all the presently preferred food species are removed.

**Larvae: 1,2**

241. Janković, L.

1959. **Quantitative ecological investigations of the gypsy moth at the locality Jakovački Ključ (report on the activity in 1959)** [in Serbo-Croatian, English summary]. Zast. Bilja 56: 109–111.

"The gypsy moth at Jakovački Ključ has been studied since 1953. In 1959 the population became latent, allowing the first study of the species in this phase of its population dynamics. Investigations were concerned with number of clusters per square unit, site of deposition, size and form of clusters, height of deposition, and percentage of hatched caterpillars. Life history was also observed. The first larvae hatched April 1, followed by mass hatching from April 5 to 10, with the last on April 18. The caterpillar stage was completed in 58 days (53 in 1958). The number of clusters differed according to the type of forest. No clusters were observed in acacia groves and old forests; 4 clusters were found on 1 ha of the thicket, 2 in a new forest, and 10.5 in a middle-aged one. The average number of eggs was 700 (503 in 1958); the percentage of unfertilized eggs was low, only 0.95 in comparison with 4.7 in 1958. The average surface of the cluster was 820 mm$^2$ in comparison with 539 the previous year. Most clusters (86.6 percent) were deposited at a height of less than 50 cm. These results, particularly the small number of clusters per square unit, the high average number of eggs in a cluster, the very low percentage of unfertilized eggs, and the height at which the clusters were deposited, show that the gypsy moth at Jakovački Ključ is in the period of latency."

**Fecundity: 2; Generation: 1,2**

242. Janković, L.
1960. **Vertical distribution of the gypsy moth (*Lymantria dispar* L.) and its ecology** [in Serbo-Croatian, English summary]. Zast. Bilja 57/58: 203–209.

The gypsy moth is found in three altitude zones in its natural range: lowland (to 300 m), hilly (300–1200 m), and mountains (+1200 m). In lowlands, life conditions are optimal. Gradations appear constantly, with a numerical peak every 3 to 5 years resulting in total browse. There is rapid increase with gradual or rapid decrease. Caterpillar stage is a maximum of 60 days. Female fertility decreases to a 200-egg average at the posteruption stage. In the hilly zone, the gradation lasts 2 to 3 years. The caterpillar stage lasts for more than 2 months. Protogny is 23 percent, and fertility is a high 689 eggs. Completely browsed areas are rare. In the mountains there is insignificant numerical variation and no tendency to hasty increase. Protogyny is a permanent phenomenon. The percentage of nonfecundated eggs increases to 100 percent. *Carabus hortensis* L. is a predator of caterpillars and larvae.

**Adults: 3; Fecundity: 12; Generation: 2,12; Larvae: 2,3**

243. Janković, L.
1970. **Certain ecological conditions of the hill and mountain populations of the gypsy moth (*Lymantria dispar* L.)** [in German, Serbo-Croatian summary]. Ekologija 5(1): 129–136.

244. Janković, L.
1971. **Certain ecological conditions of the hill and mountain populations of the gypsy moth (*Lymantria dispar* L.)** [in German]. Pages 504–505 *in*. Proc. 13th Int. Congr. Entomol., 1968. Nauk. Leningrad.

245. Janković, M., D. Zecević, and V. Vojnović.
1959. **Races of the gypsy moth in Yugoslavia (report for 1959)** [in Serbo-Croatian, English, summary]. Zast. Bilja 56: 99–107.

"Further investigations of gypsy moth races of Yugoslavia, carried out by the Biological Institute of the PR of Serbia in the course of 1959 in localities of different geographical distance, showed [the] following results: It was established that the linear size of gypsy moth eggs (length and width) progressively increased from the northern populations to the southern ones. An analogous regularity was also observed concerning the beginning of the hatching of caterpillars: The caterpillars of northern localities begin to hatch first and those of the southern localities last. Physiological endurance of hatched caterpillars to low temperatures decreased from north to south, whereas the average duration of the total gypsy moth development increased from northern localities to southern ones. Finally, the investigations made in 1959 demonstrated that the number of exuviations of female caterpillars was less with populations from northern and mountainous localities than with populations from southern and lowland localities."

**Generation: 12,13**

246. Kal'vishch, T. K.
1969. **The causal agents of mycoses of some leaf-eating insects in Siberia and Kazakhstan** [in Russian]. Mikol. Fitopatol. 3(5): 403–409.

247. Kamiya, K.
1934. **Studies on the morphology, bionomics, and hymenopterous parasites of the pine caterpillar (*Dendrolimus spectabilis* Butler)** [in Japanese, English summary]. Bull. For. Exp. Stn. Korea 18.

The morphology and bionomics of *Dendrolimus spectabilis* Butler are given. It is found in Japan, Korea, eastern Siberia, and northern China. Twenty-three hymenopterous parasites are known. One, *Apanteles liparidis* Bouché, which is widely distributed in Japan, Europe, Siberia, and America, has more than four generations a year. It infests the larvae of the gypsy moth in the first two generations and the larvae of the pine-caterpillar in the last two. Between these two, it appears to spend one or two generations on other hosts. It is known to infest *D. spectabilis, D. albolineatus, D. pini, Lymantria dispar, Notolophus postica, Euproctis chrysorrhoea,* and *Porthesia similis.* Natural enemies vary with the season. Larvae coming out of pine-caterpillars are attacked by *Hemiteles* sp., and larvae emerging from gypsy moth may be attacked by any of 10 hymenopterans. Pupae from the pine-caterpillar generations are attacked by a Coleoptera larvae and those from the gypsy moth generations by an ant.

**Instars I–III: 4**

248. Kamiya, K.
1940. **On the natural enemies of *Apanteles liparidis* Bouché** [in Japanese]. Oyo Dobutsugaku Zasshi 12(3–4): 120–122.

249. Kansu, I.
1962. **The effects of the food on the larvae of the butterflies and moths and an experiment on the gypsy moth larvae** [in Turkish, English summary]. Ankara Univ. Ziraat Fak. Yayin. 2: 116–138.

Groups of 25 gypsy moth larvae were reared in the laboratory on different food material. It was found that no larva can live on pear leaves. At 26°C and 60 to 70 percent relative humidity, mortality was 12.0 percent on oak, 23.3 percent on apple, 26.0 percent on quince, 52.1 percent on plum, and 70.0 percent on apricot. The male larval and prepupal developmental periods were 28.20 days on oak, 31.00 on apple, 27.70 on quince, 32.90 on apricot, and 36.25 on plum. For females the periods were 33.08. 33.24, 35.06, 37.60, and 38.00 days, respectively. Initial pupal weights were 451, 372, 399, 341, and 256 mg for males, and 1278, 1074, 742, and 708 mg for females, respectively. These results indicate that mortality and pupal weights are influenced by food and that oak is the most suitable host plant.
**Oak stands: 15; Larvae: 12,13; Non-oak stands: 15; Prepupae: 13; Pupae: 13**

250. Karas'ov, V. S. and T. I. Satarova.
1973. **The effect of tannins from *Salix, Populus,* and *Quercus* on the development of *Porthetria dispar*** [in Ukrainian]. Zakhist Rosl. 17: 44–46.

251. Karnig, J. J., and W. H. Lyford.
1968. **Oak mortality and drought in the Hudson highlands.** Black Rock For. Pap. 29. Harvard Black Rock Forest, Cornwall, N.Y.

This discusses the high oak mortality in southeastern New York during the drought of 1962 to 1966, which affected most of the northeastern United States. Drought is very rare as a mortality factor in these areas. The effect is greater on shallow ridge soils and on susceptible species. Crown class or degree of competition is unimportant as a factor affecting loss due to drought. The mortality of oak may not have been entirely due to drought since there was severe defoliation by cankerworms (*Paleacrita vernata*) and loopers (*Erannis tiliaria*). Most heavily affected were the scarlet oak-black oak type, whose basal area declined from 46 percent baseline to 3 percent.
**Oak stands: 17,18,22,24,25**

252. Kato, M., and K. Okazaki.
1941. **The outbreak of *Liparis dispar japonica* Motschulsky (Lymantriidae) in the year of Showa 16 (1941)** [in Japanese]. Oyo Kontyu 3: 103–119.

The Japanese gypsy moth got into rice fields from adjacent forests, fed on the leaves of rice plants, and arrested plant growth. Climatic conditions in 1941, especially suitable amounts of rainfall, were thought to have been predisposing factors. The migration of the larvae to the rice began June 20. They were carried to the vicinity on silken threads, then crawled on the ground. Many drowned. *Tachina larvarum* parasites were numerous. Adults emerged from early July to mid-August.
**Adults: 1; Larvae: 1,4,12; Non-oak stands: 15,18**

253. Kegg, J. D.
1971. **Impact of gypsy moth: repeated defoliation of oak in New Jersey.** J. For. 69: 852–854.

Defoliation in Morristown, N.J. is described and the percent mortality for each of eight genera is given. Oak mortality increased with each year of defoliation, from 6 percent baseline to 28 percent after 2 years and 69 percent after 4 years. Chestnut and black oak had less than 20 percent mortality, while scarlet, white, and northern red oaks had close to 40 percent. Greatest mortality was in the 6 to 12 inch diameter breast height (dbh) class and the greater than 26-inches dbh class. Oak density decreased from 24 percent to 19 percent, and birch (which also sustained repeated defoliation) increased from 19 percent to 21 percent. Basal area of oaks decreased from 41 percent to 32 percent, with greatest losses in the 6- to 12- inch dbh class, which declined from 36 percent to 18 percent of oaks. Large oaks did not recover from repeated defoliations, and heavily defoliated trees often did not survive the winter. Oak is the genus most vulnerable to mortality following repeated defoliation. Most beech, birch, hickory, and maple recovered well after defoliation.
**Oak stands: 15,16,20,22,24,25,27,28**

254. Kegg, J. D.

1972. **Oak mortality on the rise.** New Jersey For. Pest Rep. 7(4).

After 2 years of heavy defoliation by the gypsy moth, oaks in the Newark watershed of northern New Jersey showed continued mortality 3 years after the insect population collapsed. In 1968 oak mortality was 6.5 percent; in 1969, when there was 70 to 100 percent defoliation, mortality was 14.3 percent. In 1970, also with 70 to 100 percent defoliation, it was 38.0 percent; in 1971, 58.5 percent; and in 1972, 63.4 percent. White oak sustained the greatest loss (84.1 percent) and scarlet oak the least (27.3 percent). The severity of loss may not be as great on oaks growing on the sandy soil of southern New Jersey, as least as the situation appears after one season of gypsy moth attack.

**Oak stands: 15,25,28; Generation: 2**

255. Kegg, J. D.

1973. **Oak mortality caused by repeated gypsy moth defoliations in New Jersey.** J. Econ. Entomol. 66: 639–641.

The stand under investigation is in the Newark watershed where the gypsy moth was first reported in 1968. Composition at this time was 63 percent oak with a 0.6 percent baseline mortality throughout the forest stand. Tree mortality was monitored from 1968 to 1972. The highest mortality rate occurred among the species of the white oak group. Less preferred and nonpreferred species maintained a baseline mortality. After 2 years of 75 to 100 percent oak defoliation, their density declined from 63 percent to 23 percent. Basal area of oak declined from 93.8 to 41.4 feet. Representing tree condition by percentage of dead branches proved effective in forecasting oak mortality for the following year. Weakened trees were attacked by *Agrilus bilineatus* (Weber) and the root rot fungus *Armillaria mellia* (Vahl). "Mortality tended to be greater on southeastern, southern, and southwestern aspects where moisture stress was greatest."

**Oak stands: 15,16,20,21,22,24,25,27,28**

256. Kelus, O. G.

1941. **Geographical distribution and areas of the gypsy moth outbreaks in the USSR** [in Russian]. Vestn. Zashch. Rast. 1941(1): 45–52.

257. Keremidchiev, M. T.

1972. **Dynamics of outbreaks of the gypsy moth (*Lymantria dispar* L.) in the People's Republic of Bulgaria** [in Russian]. Pages 51–54 *in* Proc. 13th Int. Congr. Entomol., 1968. Vol. 3 Nauk, Leningrad. (English transl. by U. S. Dep. Agric. For. Serv. Telecom GM-75-7033).

From 1891 to 1932 gradations lasted 3 years, with depression periods of 5 to 11 years. The length of the gradations increased to 4 to 5 years, with 2 to 3 year depressions during the period from 1932 to 1946. A 12-year gradation broke out in 1946. Two widespread gradations (1946 to 1957 and 1962 to 1967) broke out after a rise in the sum of mean daytime air temperature by 2.3 percent to 9.0 percent in April, May, and June together with a decrease in precipitation to half of normal. Drought causes a biochemical change in the leaves. Mass reproduction of the gypsy moth occurs in low regions with favorable temperatures where forests originate from shoots. Outbreak is also encouraged by the extensive spread of cattle grazing and the human activity of felling deciduous trees with low age turnover. Food plant preferences are more apparent early in the gradation. Fertility and survival rates are contingent on food quality. Food quantity affects adult size and sex ratio. At the beginning of a gradation, the ratio between male and female is 55:45, at culmination it is 34:66, and at the end of the gradation it is 78:22. Only after the third year of the gradation do the numbers of parasites and predators increase significantly.

**Oak stands: 15; All stands: 15,23; Generation: 2,3,4,12**

258. Khanislamov, M. G., L. N. Girfanova, Z. S. Yafaeva, and R. K. Stepanova.

1958. **Mass reproduction of the gypsy moth in Bashkiriya: studies on the foci of pests of Bashkirian forests** [in Russian]. UFA 1958: 5–45.

Gypsy moth outbreaks in Bashkiriya are repeated every 8 to 13 years. Progradation is related to meteorological conditions (a combination of low precipitation to temperature ratios in May and June following a very severe winter). The primary foci of the gypsy moths are in the relatively open forest-steppe zone; the average duration of outbreaks there is 6 years. The insects begin to die away under the action of biocoenotic factors.

Most important in limiting the gypsy moth population are the entomophages, which exterminate more than 80 percent of the individuals at the foci. Under laboratory conditions, the gypsy moth feeds best on poplar, aspen, and birch; under natural conditions during latency, the gypsy moth prefers aspen, birch, and oak-birch plantings, therefore these species should be kept under constant observation.
**Generation: 2,4,12; Non-oak stands: 15**

259. Khanislamov, M. G., L. M. Girfanova, Z. S. Yafaeva, and R. K. Stepanova.
1962. **Conditions under which foci are formed and numerical increases occur in the gypsy moth (*Ocneria dispar*) in Bashkiriya** [in Russian]. UFA 2: 32–66.

During latency the gypsy moth was concentrated primarily in disorganized deciduous stands with low cover. However, the foci were not stable. Eggs were frequently found on birch, which are distinguished by early foliage. The gradation emerges from latency when there is a spring drought followed by a severe winter. Outbreak occurs more rapidly in stands where the population density during progradation is higher and the number of natural enemies fewer. A limited number of pests is affected by diseases and specialized parasites. Large-scale reproduction of the gypsy moth depends upon the physiological condition of growing stock. Leaves from weakened trees are more nourishing for the pests. Individuals from developing foci are more sensitive to the physiological condition of food plants than individuals from populations in latency. A bibliography of 83 references is included in this article.
**All stands: 19; Generation: 2,12; Non-oak stands: 15**

260. Khanislamov, M. G., and Z. S. Yafaeva.
1964. **Biological regulation of pest populations in various stages of their developmental cycle.** Pages 165–167 *in* Biological control of agricultural and forest pests. Inst. Biol. Bashkiria State Univ., UFA m.d.

The authors observed the gypsy moth in two of its foci in Bashkiriya for 11 years, beginning in 1952 at the gradation climax and ending in 1962, with the insect in total decline in one area and in the beginning of a slow rise in the other. They found that the role of parasites changed with the phase of the gradation and that different parasites were important in each focus: Diptera predominated in the site on the Russian plains and Hymenoptera in the southern Urals. They noted further that the efficacy of the various biotic controls varied with the phase of the gradation.
**Generation: 2,4,6**

261. Kireyeva, I. M.
1969. **Specific developmental features of gypsy moth (*Porthetria dispar* L.) under different photothermal conditions** [in Russian]. Vestn. Zool. 3(1): 86–88.

The effect of temperature (16, 22, 28, and 32°C) and illumination (24-hour illumination, 17.7-hour illumination, and 24-hour darkness) on pupal development was investigated. At low temperatures, with a prolonged illumination period, the duration of the pupal development is shortened and viability increases. At high temperatures, the shortest development time and greatest viability are observed at 17-hour illumination. The effect of illumination depends on temperature conditions and is most pronounced at a low temperature.
**Pupae: 12,13**

262. Kireyeva, I. M.
1973. **Some features of *Porthetria dispar* L. population in the Kherson and Transcarpathian regions** [in Ukrainian, English summary]. Dopov. Akad. Nauk. Ukr. RSR, Ser. B. Heol. Heafiz Khim. Biol. 6: 565–568.

"The investigations were performed in the territory of the Transcarpathian and Kherson regions [which] differ in their [topographical] relief and climate. The experiments resulted in a conclusion that the geographic populations of *Porthetria dispar* L. differ in a number of ecological peculiarities (time of caterpillar birth, duration of development, and survival ability) which indicate their adaptation to the local life conditions. Seasonal rhythm of temperature is one of the main factors determining adaptation of the insects' life cycle."
**Generation: 12**

263. Klepac, D.
1959. **The determination of loss of growth in forests attacked by the gypsy moth (*Lymantria dispar*)** [in Serbo-Croatian, French summary]. Sum. List. 83(8–9): 280–290.

264. Kochetova, N. I.
1968. **Sex ratio in *Anastatus disparis* Rusch. (Hymenoptera, Eupelmidae) under its development on different hosts** [in Russian, English summary]. Zool. Zh. 47(10): 1572–1574.
"The investigations carried out on *Anastatus disparis* Rusch. have shown that, . . . [when infecting] the usual host (*Porthetria dispar*), the developing progeny consists of both males and females . . . [when infecting] unusual hosts, the progeny consist only of males. This can be explained by the fact that the usual host stimulates . . . both fertilization and egg laying, whereas unusual ones stimulate only egg laying."
**Eggs: 4**

265. Kokhmanyuk, F. S.
1964. **Effect of different conditions on the disposal of the eggs laid (oviposition) by the gypsy moth *(Ocneria dispar)*** [in Russian]. Nauchn. Dokl. Vyssh. Shk. Biol. Nauk. 1: 24–26.
In stands lacking undergrowth and an herbaceous cover, eggs are deposited on dry places, with a preference shown for dead trees. Temperature and humidity during oviposition affect the height at which eggs are deposited. Most clusters are on the southern sides of trunks and structures.
**Adults: 1, 12**

266. Kokhmanyuk, F. S.
1964. **Oviposition in *Ocneria dispar*** [in Russian, English summary]. Zool. Zh. 43(2): 290–291.
"About 20 percent of *Ocneria dispar* females oviposit at 2 to 3 sites at a height of more than 100 cm above ground level. Solar rays, wind, and humidity cause the fractional oviposition in *O. dispar*. The greatest number of eggs laid by *O. dispar* occurs from 2 to 6 p.m. on the 3rd to 4th day after the onset of oviposition."
**Adults: 1, 12**

267. Kokhmanyuk, F. S.
1965. **Gypsy moth (*Ocneria dispar*) control in the roadside plantations.** Zashch. Rast. 10(4): 30–31. (Transl. from Russian by C. E. Nikiforoff. NAL Transl. 17032.)
The most common habitats of the gypsy moth were found to be roadside plantations, especially along the Brest-Moscow highway where willows were completely defoliated in 1956, 1958–59, 1961, and 1963. In the center of the infestation there were from 21 to 58 oviposition sites per 10 trees; at 5 to 7 km, 7 to 18 sites per 10 trees; at 10 to 15 km, no oviposition sites. The population level remained steady, but the center of the focus shifted, probably owing to first-instar dispersal by wind (to at least 3 to 4 km) and to some females' flying into automobile headlights.
**Adults: 1, 2; Instars I–III: 1, Non-oak stands. 15**

268. Kolybin, V. A., and L. M. Zelinskaya.
1969. **Ecologo-physiological peculiarities of *Porthetria dispar* L. population in the lower Dnieper area: Communication I. Structure of population** [in Russian, English summary]. Vestn. Zool. 3(3): 37–42.
"The ecological analysis of *Porthetria dispar* population structure in the lower Dnieper area showed that it consists of four micropopulations connected with certain fodder plants and isolated during separate stages of a life cycle of the insect. Such dismembering of *P. dispar* population into separate micropopulations favors the maintenance of the pest quantity and makes pest control more difficult."
**Generation: 2**

269. Kolybin, V. A., and L. M. Zelinskaya.
1971. **Ecologo-physiological peculiarities of *Porthetria dispar* L. population in the lower Dnieper area: Communication II. Parasites and diseases** [in Russian, English summary]. Vestn. Zool. 5(1): 26–31.
"Under conditions of the lower Dnieper area, about 20 species of parasitic and carnivorous insects are found to affect *Porthetria* dispar (L.) *Anastatus disparis* Ruschka is of greatest importance in limiting the number of the pest at the egg stage, *Apanteles vitripennis* Hal at . . . [the larval] stage, and Sarcophagidae at . . . [the pupal] stage." In the region under investigation, the mortality of *P. dispar* (L.) has been established to be caused by polyhedrosis and microsporidiosis. "The role of parasites, carnivorous insects, and diseases in limiting the quantity is not the same in different micropopulations and changes according to the pest gradation phases."
**Eggs: 4; Generation: 2, 6; Larvae: 4; Pupae: 4**

270. Kolybin, V. A., L. M. Zelinskaya, and V. V. Barabanova.
1971. **Ecophysiological characters of the population and the mass appearance of *Porthetria dispar* L. in the lower Dnieper region** [in French]. Pages 400–401 *in*. Proc. 13th Int. Congr. Entomol., 1968. Nauk Leningrad.

271. Komárek, J.
1950. **The different effects of entomoparasites and diseases on invasions of insects** [in Czechoslovakian, Russian and English summaries]. Sb. Cesk. Akad. Zemed. Ved. 23(3/4): 232–237.
"The paper discusses the results of an extensive attempt to stop the spread of some harmful phytophagous insects introduced from Europe into North America by means of the importation of entomophagous parasites and foes [predators?] from their original European home. The basis of the attempt was the idea that by the transfer of the parasites and by artificial breeding such a decrease in the hosts would be achieved that their spread in America would stop." Cases are cited of phytophagous Lepidoptera and Hymenoptera from Czechoslovakia whose outbreaks fluctuate. "The species *Lymantria dispar, Pyrausta nubilalis, Gilpinia hercyniae (Diprion polytomum), Semasia rufimitrana,* and other Tortricidae living on firs are cited. In Czechoslovakia the ecology of these species was studied with regard to the origin of the eruptions and to the significance of entomoparasites and diseases that limit a fluctuating overmultiplication. The different effect of parasites and infectious diseases was recognized. Empirical experience conformed that in the listed species of Lepidoptera and Hymenoptera the parasites are never able to control their host so as to prevent it from multiplying from time to time in mass in its original home. By themselves, the parasites cannot stop an eruption once started. The mass multiplication is terminated in most harmful insects always by the epidemic spread of a virus infection, except in the species *Pyrausta nubilalis,* where no infectious epidemic could be ascertained . . . The experience obtained in North America in the period in which the importation of parasites and their multiplication was carried out intensively agrees in general with the observations made in Czechoslovakia on the different effect of parasites, wild animals, and diseases on the invasions of harmful phytophagous Lepidoptera and Hymenoptera. A graph . . . shows the curves for the host, the parasites, and the virus disease in the case where the host begins to multiply massively and eruptively."
**Generation: 2, 4, 7, 12**

272. Komárek, J., and V. Skuhravý.
1952. **The influence of temperature on periodical outbreaks of the gypsy moth (*Lymantria dispar* L.)** [in German, Russian and Czechoslovakian summaries]. Cas. Cesk. Spolecnosti Entomol. 49(1–2): 15–30.

273. Kondakov, Y.P.
1961. **Distribution of egg clusters of the gypsy moth in forests of the southern part of the Krasnoyer region** [in Russian]. Uch. Zap. Krasnodar. Gos. Pedagog. Inst. Im. Trinadtsati-Letiya VLKSM. 20(2): 17–32.
Data from 1954 to 1956 indicate that the base of the bole of thick-trunked pines is the primary site for gypsy moth egg clusters in lowland pine forests. Rarely, the clusters are found higher than the level of snow cover or on birch. Thus clusters of eggs withstood temperatures down to −53°C. Seven species of birds destroyed up to 35 percent of the overwintering eggs. Caterpillars that hatched on the pines were carried by wind to favored foods, birches in gardens, and green plantations. In the mountains eggs are laid in cracks and clefts of unprotected rocks. The larvae are windblown into mountain valley forests where they feed primarily on birch and larch.
**Adults: 1; Eggs: 9, 12; Instars** I–III; **1**

274. Kono, H.
1938. **On the influence of sunspot periods on the periodic outbreaks of *Porthetria dispar* (L.) in Japan** [in Japanese]. Bot. Zool. Tokyo 6(8): 1361–1376.

275. Kono. H.
1939. **On the influence of sunspot periods on the periodic outbreaks of *Porthetria dispar* (L.) in Japan,** II [in Japanese]. Bot. Zool. Tokyo 7(8): 1356–1358.

276. Kono, H., and Y. Sugihara.
1940. **Observations on the oviposition of *Porthetria dispar* L.** [in Japanese]. Oyo Dobutsugaku Zasshi 12(2): 69–74.

277. Kononova, N.E.
1964. **Survival of leaf-devouring insects in relation to the condition of the plant** [in Russian, English summary]. Zool. Zh. 43(1): 37–42.

"Physiological conditions of plants cause a strong effect upon the survival of larvae (especially those of early instars), upon the time of their development, and upon the fecundity of the imago. An improvement [in] the development of the plant due to application of fertilizers and [to] watering increases its resistance to leaf-devouring insects, decreasing larval survival. Deterioration of the plant condition increases survival of the larvae, providing for their fast development, and increases the number of the eggs deposited, which [creates] a sharp increase in population. The age of the leaves and related anatomo-morphological peculiarities also play a protective role against damage caused by young larvae which are unable to gnaw the upper layer of "old" leaves and perish from starvation. In the case of an artificial injury [to the] epidermis of such leaves, larvae survive better, while often perishing on well-developed plants with marked symptoms of intoxication. This [points out] the presence in oak leaves of protective subtances of a toxic nature against the larvae of specialized pests."

**All stands: 23**

278. Kovačević, Ž.
1926. **Malacosoma neustria L. and *Porthetria dispar* (L.) and their parasites** [in German]. Anz. Schaedlingskd. 2(8): 93–94.

279. Kovačević, Ž.
1954. **The importance of the polyhedry for the mass appearance of some insects** [in Serbo-Croatian, English summary]. Zast. Bilja 23: 3–20.

The expression of latent virus is not only dependent on quantity and quality of food but also on the genetic susceptibility of the insect. This may be on an individual, population, or race level. Other factors affecting the expression of virus are macroclimate and microclimate.

**Generation: 7**

280. Kovačević, Ž.
1956. **Food-plant selection and the occurrence of plant pests (a contribution to the knowledge of population dynamics)** [in German]. Anz. Schaedlingskd. 29(7): 97–101.

The influence of food choice on the life processes and population dynamics of four polyphagous agricultural and forest pests was investigated in the laboratory. Gypsy moth eggs were collected during retrogradation. Larvae were fed on one of the following, any of which might be chosen by them in the field: oak, beech, hornbeam, apple, or plum. Only those larvae fed on oak survived from year to year. The food source also affected the development period and the number of instars. It is concluded that the duration of a gradation is not dependent on starvation, but on the physiological effect of the main nourishing plant. For insects fed on oak the cause of mortality varied during the gradation: in progradation, physiological debility was the major cause (parasites and predators were not factors in these controlled experiments), while polyhedral virus became important during retrogradation. However, with unfavorable nutrition, physiological debility was the major cause even during retrogradation. In different regions of the country, different species of oak functioned as the main sustaining food, suggesting genetic differences in the groups of gypsy moths.

**All stands: 23; Larvae: 2, 7, 13; Generation: 2, 12; Oak stands: 23.**

281. Kovačević, Ž.
1958. **Pathogenic microorganisms as companions to and as mortality factors of the gypsy moth, *Lymantria dispar* L., and the American fall webworm, *Hyphantria cunea* Drury** [in German]. Anz. Schaedlingskd. 31: 148–150.

282. Kozhanchikov, I. V.
1940. **The importance of the physical conditions of environment upon the development of the eggs of the gipsy moth (*Lymantria dispar* L.)** [in Russian]. Vestn. Zashch. Rast. 1940(3): 3–16.

283. Kozhanchikov, I.
1949. **The importance of seasonal changes of food plant leaves in the development of gypsy moth (*Ocneria dispar* L.).** [Transl. from Rus-

sian.] Dokl. Akad. Nauk. SSSR Biol. Sci. Sect. 66(6): 1203–1206.

One possible explanation for the univoltine life cycle of the gypsy moth is the phenology of vegetation. Groups of larvae were fed on spring, summer, or fall vegetation of oak, willow, or mountain ash. In all cases the survival rate of those larvae fed spring foliage was much higher. Total mortality resulted in those fed with summer foliage from mountain ash. Of the larvae that survived on willow foliage, the individuals reared on spring foliage weighed the most. The duration of development remained constant. Larvae fed on fall oak foliage added an instar and took longer to develop.

**Generaton: 12; Larvae: 13**

284. Kozhanchikov, I. V.
1952. **The question of vital thermal optimum: IX. Temperature scale as a factor in the development of the gypsy moth and the oak saturnid** [in Russian]. Entomol. Obozr. 32: 27–42.

285. Kudler, J.
1969. **Problems and feasibility of the use of bacteria for control of defoliating forest insect pests** [in German, Russian and English summaries]. Rep. Conv. Ger. Entomol. 10,1965, Dresden 80: 451–455. Dtsch. Akad. Landwirtsch. Wiss. Ber.

"The present contribution discusses findings and experiences of investigations into the use of entomogenous bacteria for control of some clean eating pests from the order Lepidoptera in Czechoslovakia. The most suitable control factor seems to be *Bacillus thuringiensis*. Application and resulting theoretical aspects of its use are included."

**Larvae: 5**

286. Kulman, H. M.
1971. **Effects of insect defoliation on growth and mortality of trees.** Ann. Rev. Entomol. 16: 289–324.

"Defoliation and growth measurements relate to a complex of factors. Flower production and the size, abundance, food storage capacity, hormone production, photosynthetic efficiency, and respiration of foliage vary with tree age, species, season of the year, and the age, exposure, and crown location of the foliage. These must be considered when making quantitative statements of foliage loss because they affect foliage growth and production, tree survival, and the quantity and/or location of reduction in shoot and diameter growth. Variations in ring growth at different vertical levels in the trunk and the separate response of spring and summerwood growth are especially important. . . The importance of foliage for growth and survival decreases directly with its age and inversely with its exposure. Evergreen conifers usually survive a single complete defoliation in spring before the elongation of the new foliage. Later defoliation that includes the new foliage often causes mortality. Pines and deciduous trees usually show an immediate response to defoliation if it occurs before shoot or ring growth is completed. Growth responses in spruce and firs are often delayed for one to several years. The first growth responses in the trunk are usually found within the living crown, but considerable variation is reported. Most deciduous trees survive several defoliations and produce new sets of leaves in the same season. Secondary agents, such as site, tree age, and climatic conditions influence the survival of defoliated trees."

**All stands: 15,24,25,26; Review; bibliography**

287. Kumar, T. P.
1974. **Occurrence of *Lymantria obfuscata* Walker, the Indian gypsy moth, as a pest of cacao in south India.** Curr. Sci. (Bangalore) 43(9): 395.

The Indian gypsy moth is a pest of forest and fruit trees in certain regions of north India and is now for the first time found in south India feeding on tender leaves of cacao. The Indian gypsy moth is closely related to *Lymantria dispar*.

**Non-oak stands: 15**

288. Kurir, A.
1943. **The influence of abiotic environmental factors on eggs of the gypsy moth (*Lymantria dispar* L.) during winter diapause. I. The effect of ice** [in German]. Z. Gesamt Forstwes. 75/69(4/6): 105–132.

289. Kurir, A.
1944. ***Anastatus disparis* Ruschka egg parasite of *Lymantria dispar* L.** [in German]. Z. Angew. Entomol. 30(4): 551–586.

*A. disparis* has one generation per year in Central Europe, as does its host, since it usually attacks fresh eggs of the gypsy moth. One parasite develops per host. The adult lives about 15 days.

Within the host egg, *A. disparis* can tolerate temperatures down to −26°C. Two new secondary parasites, *Torymus anastativorous* n.sp. Fahringer and *Tyndarichus kuriri* n.sp. Fahr., are reported.

**Eggs: 4**

290. Kurir, A.
1953. **The food plants of the gypsy moth (a contribution to the knowledge of its feeding habits)** [in German]. Z. Angew. Entomol. 34(4): 543–586.

291. Kuwayama, S.
1929. **Activity of *Lymantria* (*Porthetria*) *dispar* Linn. in Hokkaido** [in Japanese]. Oyo Dobutsugaku Zasshi 1(2): 106–109.

292. Lamamié de Clairac, A. P., and C. M. García.
1972. **Biology of the gypsy moth (*Lymantria dispar* L.) in the province of Salamanca in 1972** [in Spanish]. Bol. Inf. Plagas 99: 3–14. Servicio de Defensa contra Plagas e Inspeccion Fitopatologica, Salamanca, Spain.

293. Langhoffer, A.
1926. **The gypsy moth and the destruction of our oak forests** [in Serbo-Croatian, German summary and Table of Contents]. Zagreb. Sveuc. Zavod sum. pokuse. An. Exp. For. 1: 150–233.

294. Langhoffer, A.
1929. **The large numbers of oak destroyed in Yugoslavia considered from the entomological standpoint** [in German]. Congr. Int. Zool., 1927. 10(2):1196–1203. (English transl. by U.S. Dep. Agric. For. Serv. Telecom GM-75-7093)

The cause of widespread oak wilt in Yugoslavia is moth defoliation of the first foliage, followed by oak mildew (*Microsphaera alpitoides* Griff. and Maubl.) attack on the newly refoliated sprouts, and perhaps followed by beetles destroying the cambium of the weakened trees. Prior to 1909, when oak mildew was introduced to Yugoslavia, gypsy moth defoliation generally caused a decrease in acorn production and in annual growth, but did not cause mortality.

**Oak stands: 15, 16, 23, 25**

295. Leius, K.
1961. **Influence of food on fecundity and longevity of adults of *Itoplectis conquisitor* (Say) (Hymenoptera: Ichneumonidae).** Can. Entomol. 93: 771–780.

"The females of many species of chalcids, braconids, pteromalids, and ichneumonids feed on the body fluids or hemolymph of their host. The fact that the adult males do not partake of this food indicates that such feeding may be associated with egg production. Carbohydrate foods, in addition to the body fluids of the host, are essential to egg production in certain species. Feeding on the host by females of certain hymenopterous parasites increases their value as control agents. This feeding sometimes may be more important than parasitism as a cause of host mortality. *Itoplectis conquisitor* (Say), a host-feeding parasite, is considered in this paper." Females were observed feeding on host body fluids exuded when the ovipositor pumped up and down. Adults were also observed feeding on flowering plants, particularly umbelliferous ones, and on aphid honey dew. Parasite adults do not feed on the first day of emergence. For the next week, they feed only on carbohydrate and vegetable protein; then the female punctures the host pupae and feeds on body fluid. There is no evidence that it feeds on other host tissue. On the first day of feeding on body fluids, no eggs are laid, but an average of 12 pupae are punctured. On the second day, twice as many are punctured and six eggs are laid. At the peak, five or six punctures are made for each egg deposited. This series of experiments was conducted at 72°F. Females fed on body fluids, carbohydrates, and pollen lay more eggs and live longer. Males fed on host pupae do not live longer, and longevity of males decreased when they were fed on honeydew.

**Pupae: 4**

296. Leonard, D. E.
1966. **Differences in development of strains of the gypsy moth, *Porthetria dispar* (L.).** Conn. Agric. Exp. Stn. Bull. 680. 31p.

"The purpose of this investigation was to establish a reference point or base for subsequent study of biological differences in the gypsy moth and their possible effects on population dynamics. Even in this preliminary study, substantial differences

within and between strains are evident. A small percentage of gypsy moth larvae of both sexes from Connecticut and Quebec, Canada, underwent an additional larval instar. Extra-instar larvae were found in 11 of 12 strains, with a higher incidence of extra-instar males than females. According to Goldschmidt, the variation in number of molts is controlled by three alleles of the T gene. The occurrence of seven larval instars in some females suggests that other alleles might be present. Comparison of normal larvae showed that male and female development times were about equal in instars I and II, but males took longer than females to complete instars III, IV, V, and the pupal stage. Extra-instar larvae took longer to complete the first two instars than normal larvae, but all other immature stages proceeded at a rate faster than normal larvae. The total development time from egg hatch to adult for five males was 58.77 days at 23 °C and 44.61 days at 27 °C, whereas six females took 61.65 days at 23 °C, and 48.73 days at 27 °C. This shows a marked tendency toward protandry. However, six males developed in 62.59 days at 23 °C, and 48.75 days at 27 °C, closely approximating the times of six females. Seven females took the longest time to develop; 68.29 days at 23 °C, and 50 days at 27 °C. Larvae that underwent an aditional molt tended to lag in their development during the first two instars, and this lag may have been due to the wandering habits of these larvae. During what would normally be the last instar (V in males and VI in females), those larvae that underwent an additional molt had a differing behavioral pattern. Normally, in the last instar, larvae do not construct any silken webbing until the prepupal stage. Those that molt again construct a silken mat early in the stadia and cease feeding on the 5th or 6th day. The molt occurs about a week after the instar begins, contrasting to a stadium of about 2 weeks if prepupae are to be formed. Also, the tubercules on the dorsum of six males and seven females are a more brilliant red color. Pupal mortality was highest in larvae that underwent an additional molt. An increase in temperature, from 23 °C to 27 °C, reduced development time by nearly 25 percent. Lack of illumination had little, if any, influence on development time. The widest range in variation of development time occurred at 23 °C. The decrease in development times at 27 °C was not due to a differential rate in any one stage, for the percent of time spent in each stage did not differ from specimens reared at 23 °C. The fastest developing strains were those collected in Canada. This suggests adaptation of these strains has occurred in a relatively small number of generations. Using frass as an indicator of feeding, most feeding occurs during the last larval instars. The frass produced during instars I and II is about 1/40th of the total for males and about 1/160th of the total for females. In instar III, five males produced slightly more frass than six females, but six males produced noticeably less frass than five males. In instar IV, extra-instar larvae produced the least frass, with five males producing the greatest amount. In instar V, five males accounted for the most frass, but six females also fed heavily during this instar. Extra-instar males and females produced about the same amount of frass. During instar VI, six females produced about 4 times the amount of frass of last-instar males. The last-instar frass production of six males was equivalent to the frass produced by the last-instar five males, but seven females produced less frass than six females during their respective last larval instars. The ratio of dry weight of frass to pupal weight was quite uniform between strains, but slightly lower for males than females. There was a tendency for the pupal weights of the earliest emerging adults to be heavier than those of later emerging adults."

**Larvae: 2,13: Pupae: 13**

297. Leonard, D. E.
1967. **Parasitism of gypsy moth in Connecticut by *Brachymeria intermedia*.** J. Econ. Entomol. 60: 600–601.

Leonard had previously determined that this parasite was established in North America. This study was made to determine its efficiency as a parasite. The total percentage of gypsy moths it parasitized was 1.7 percent, with a high of 4.7 percent in East Lyme. Equal numbers were recovered from male and female pupae. Dipteran parasites emerged from 25 percent of the total number of pupae; another 25 percent did not emerge owing to polyhedral virus disease. These are laboratory figures; in the field the survival rate is lower as a result of predation. The percent of *B. intermedia* parasitism in collections made in Portugal and Spain in 1925 ranged from 2.8 to 4.1 percent.

**Pupae: 4,7,12**

298. Leonard, D. E.

1967. **Silking behavior of the gypsy moth, *Porthetria dispar*.** Can. Entomol. 99: 1145–1149. 1145–1149.

"Newly hatched larvae remain near the egg and consume a part of the chorion." There is little movement for 12 hours after hatch. After feeding, gypsy moth larvae construct silk resting mat on which they remain. The mat provides a point of attachment for exuvia and therefore facilitates molting. Prior to molting this mat is reinforced or a new, dense, molting mat is constructed. "Late in the last larval instar a sparse cocoon is constructed. When larvae are starved, a shift in behavior is noted, with increased locomotion, irritability, and the trailing of a strand of silk as larvae wander. First-instar larvae, quiescent and anchored on resting mats, are not readily induced to spin down on silk threads, hence are not readily dispersed by wind. Hungry first-instar larvae, more apt to be spinning down, are presumed to be more readily dispersed by wind. Larvae that undergo an additional instar have a longer prefeeding phase and might be more readily dispersed than normal larvae." Hunger causes a change in behavior, which may explain the change in periodicity of older larvae at high densities. Hunger induces wandering, which may disrupt the feeding of other larvae. Thus the diel periodicity of an entire infestation could be rapidly disrupted even though foliage is not entirely consumed. This behavioral change insures dispersal of larger larvae away from an infestation where food would be depleted before development was completed.

**Larvae: 1,2; Prepupae: 1**

299. Leonard, D. E.

1968. **Additional larval instars: inducement and effect on gypsy moth population biology.** Paper presented at Entomol. Soc. Am., Dallas, 1968.

When larvae are starved, crowded, or reared in a cool environment during instar I, the percentage of larvae with extra instars increases. Substantial differences are found in the propensity for extra instars among individual egg masses. Extra instars correlate with the size of the eggs. As the size of the eggs diminishes, the percentage of extra instars increases. Larvae with extra instars exhibit prolonged first instar, shorter pupal stage, longer development time to adulthood, and higher pupal weight. The prolonged first instar is due to a longer prefeeding phase, which increases the possibility for wind dispersion. Higher pupal weight positively correlates with increased fecundity, thereby increasing the probability of establishment in uninfested areas. This mechanism is believed to be environmental as well as genetic. This is supported by the fact that extra instars apparently occur in the same generation that is initially stressed.

**Generation: 2,12,13**

300. Leonard, D. E.

1968. **Diapause in the gypsy moth.** J. Econ. Entomol. 61: 596-598.

"Rearing *Porthetria dispar* (L.), through one generation at light regimes of 11, 13, 15, 17, and 19 hours per 24-hour day at temperatures of 19.5 °C and 28 °C had no influence on the induction or termination of dispause. Rearing temperature of 28 °C caused egg mortality. A few eggs obtained in rearings at 19.5 °C hatched without chilling. However, this hatch occurred 14 to 18 weeks after oviposition. This hatch of unchilled eggs appears to be analogous to the frequent observations in nature of egg hatch in the fall. Treatment of eggs up to 24 hours old with hydrochloric acid did not affect induction of diapause." Results suggest an obligatory diapause.

**Generation: 1,12**

301. Leonard, D. E.

1968. **Effects of density of larvae on the biology of the gypsy moth, *Porthetria dispar*.** Entomol. Exp. Appl. 11: 291–304.

"The crowding of larvae of *Porthetria dispar* in laboratory cultures induced physiological and morphological differences. Larvae that were crowded developed faster than isolated larvae, but the development of instars varied in a characteristic manner. In crowded larvae (1) instar I was longer, (2) instars II to IV were shorter; (3) in males the penultimate and last instar were shorter; (4) in females the penultimate and last instar were longer; and (5) in both sexes the pupal period was shorter. The pupal weights from crowded larvae were less, indicating a loss of fecundity. Crowding larvae increased the percentage of larvae that had increased survival. The coloration of adult males reared in crowded cultures was lighter than the coloration of adults reared in isolated cultures.

"There was a weight difference of 35 percent for female pupae and 20 percent for male pupae be-

tween those in dense and in sparse populations. Crowding also caused an increase in the number of extra-instar larvae. In dense populations, adults formed earlier than in sparse populations in nature. This is tentatively explained as follows: Since crowded larvae show a greater number of extra-instar larvae, and since these larvae have a longer prefeeding stage during which increasing hunger can cause an increase in silking, they are more likely to be dispersed by wind. Thus, sparse populations spread by wind have more extra-instar larvae and show later adult emergence.
**Larvae: 1,2**

302. Leonard, D. E.
1968. **Sexual differential in time of hatch of eggs of the gypsy moth.** J. Econ. Entomol. 61: 698–700.
Female larvae hatch before male larvae. Because the development time of the males is shorter than that of the females, the males are the first to pupate. The male adults emerge 3 or 4 days prior to the females. This might be a mechanism to insure that mature males are available for eclosion when the females emerge, even in sparse populations.
**Generation: 1,13**

303. Leonard, D. E.
1969. **Intrinsic factors causing qualitative changes in population of the gypsy moth.** Proc. Entomol. Soc. Ont. 100: 195–199.
"A change in the quality of individuals of the gypsy moth can be induced by several intrinsic and extrinsic factors. This change is expressed by a prolongation of instar I, an increase in larval activity during instar I, and an increase in the number of larval instars. The lag in development at instar I is associated with a longer prefeeding phase during which larvae are more active. These active larvae are more readily dispersed by wind. The behavioral shift can be induced during instar I by crowding, starvation, or cool temperature, or in the maternal generation by factors affecting the size of eggs. The most important effect of the qualitative change on the population biology is that it provides a mechanism for numerical self-regulation that responds rapidly to changes in population density, and is more efficient than if it were dependent solely on selection for expression. A new approach to control by prevention of the qualitative change is suggested, whereby populations would be maintained at sparse levels where suitable host plants prevail to suppress outbreaks and subsequent widespread dispersals of larvae."
**Generation: 2,12,13**

304. Leonard, D. E.
1970. **Effects of starvation on behavior, number of larval instars, and developmental rate of *Porthetria dispar*.** J. Insect Physiol. 16: 25–31.
"The behavior, number of larval stadia, and developmental rate of the gypsy moth, *Porthetria dispar,* can be altered by deprivation of food. The behavioral change is an increase in locomotory activity associated with hunger. The number of larval instars can be increased by food deprivation during instar I, but in instars II, III, or IV no significant increase was obtained. Food deprivation early in instars II, III, or IV reduced the numbers of subsequent ecdyses. When food was withheld early in an instar, the rate of development was accelerated during the remainder of the instar. The removal of food just before the cessation of feeding prior to apolysis also accelerated development." Starvation enhances dispersal, which is advantageous for survival of larvae in dense populations.
**Instars I–III: 1,12; Instars IV–VI: 1,12; Larvae: 13**

305. Leonard, D. E.
1970. **Feeding rhythm in larvae of the gypsy moth.** J. Econ. Entomol. 63: 1454–1457.
"The feeding rhythm of larvae of *Porthetria dispar* (L.) was determined from field observations. In stages I through III larvae began feeding at dawn, but not when temperatures were below 45°F. The peak of feeding occurred in the morning, with some feeding observed throughout the day. When not feeding, or at night, larvae remained quiescent on the undersides of leaves. At stage IV there was a sharp shift in the feeding rhythm, with feeding initiated in the evening and reaching a peak at sunset. About midnght, feeding activity began to decline, with small increases in feeding noted before sunrise, and between 7 and 8 a.m. The numbers of larvae feeding during the day were small." Stage I larvae fed on the upper surface of leaves, making small holes. Stage II larvae fed mostly in holes rather than on margins. Many stage III larvae continued to feed at these sites, enlarging the holes considerably. Some fed from the undersides of the leaves and some at leaf

margins. Stage IV to VI larvae fed almost exclusively on the margins of the leaves.
**Instars I–III: 1,12; Instars IV–VI: 1,12**

306. Leonard, D. E.
1970. **Intrinsic factors causing qualitative changes in populations of *Porthetria dispar* (Lepidoptera: Lymantriidae).** Can. Entomol. 102: 239–249.

"Evidence is presented to suggest that the gypsy moth, *Porthetria dispar* (L.), is numerically self-regulating through a shift in the quality of individuals induced by changes in nutrition. This qualitative change affects dispersal, behavior, developmental rate, and fecundity, and this provides *P. dispar* with the ability to respond to intrinsic and extrinsic factors faster and more efficiently than if dependent on selection. Adaptability is further facilitated because the change in quality can be induced either in the previous generation by the amount of nutrient reserves provided the eggs or during the current generation by hunger, crowding, or cool temperature. This change is best characterized by an increase in the number of larvae with additional instars. In these larvae, a prolongation of instar I and a shift in behavior increase their potential for dispersal. The similarities and differences between *P. dispar* and *Malacosoma pluviale* (Dyar) are discussed."
**Eggs 13: Instars I–III: 1: Larvae 12,13**

307. Leonard, D. E.
1971. **Air-borne dispersal of larvae of the gypsy moth and its influence on concepts of control.** J. Econ. Entomol. 64: 638–641.

"*Porthetria dispar* (L.) disperses as an air-borne stadium I larva. A field study of dispersal from a dense population indicates that dispersal occurs throughout most of the duration of stadium I. Records taken at regular intervals during the day show that most dispersal occurs in late morning and closely coincides with activity of larvae. During the night, at low temperatures, or in periods of rain, larvae are inactive and few are dislodged even by strong winds. The long duration of hatch makes it difficult to prevent dispersal and get sufficient kill by a single application of a short-residual insecticide. Population management to maintain gypsy moth populations at densities too sparse to induce dispersal is suggested as an alternative method of control." Observations of larvae in ". . . dense populations in nature indicate that many larvae will not settle and feed even when there is an abundance of available food. The duration of this active stage apparently is lengthy and must influence the duration of dispersal. These larvae respond to air movement by arching their bodies, releasing their attachment to the substrate."
**Instars I–III: 1,12; Larvae: 1,12**

308. Leonard, D. E.
1971. ***Brachymeria intermedia* (Hymenoptera: Chalcididae) parasitizing gypsy moth in Maine.** Can. Entomol. 103: 654–656.

"*Brachymeria intermedia* (Nees), an introduced parasite of the gypsy moth, was recovered from gypsy moth pupae collected in Fryeburg, Maine (latitude 44°). The recovery of this parasite in Maine shortly after it was reported established on gypsy moth in Connecticut suggests that *B. intermedia* is rapidly expanding its range. The wide range of hosts attacked by the parasite, and its occurence in northern New England, make it a promising potential biotic agent on a variety of northern pest species of lepidopterans, either through natural spread or by artificial introduction." *B. intermedia* oviposits in open (defoliated) rather than in shaded areas. It emerges the second week in July.
**Pupae: 4,7; Oak stands: 15**

309. Leonard, D. E.
1971. **Effects of larval density on the population biology of the gypsy moth, *Porthetria dispar*.** Pages 519–520 *in* Proc. 13th Int. Congr. Entomol., 1968. Nauk, Leningrad.

Larvae reared individually are found to produce heavier pupae than those reared in groups. Female pupal weight is correlated with fecundity. Maturation speeds up with grouped larvae, and an increased number of individuals with an additional instar develop under these conditions. This is thought to be nutritionally induced, either maternally or through starvation, in early larval life. Larvae produced in nutritionally stressed areas remain active and suspend on silk threads, which facilitates wind dispersal. Those larvae that survive and develop an additional instar produce females of high fecundity.
**Fecundity: 12; Larvae: 1,12,13**

310. Leonard, D. E.
1971. **Population quality.** Pages 7–20 *in* Toward integrated control. U.S. Dep. Agric. For. Serv. Res. Pap. NE-194.

"The quality of insects comprising populations may be an important factor in the biology of that population. In the gypsy moth, qualitative changes occur primarily as a response to increasing density. They appear to be characterized by a nutritive change affecting the physiology of the insect, particularly the hormonal system." This usually induces extra-instar development. "A major response to the qualitative change is an increase in dispersal. Such a density-regulated mechanism to induce dispersal can operate more rapidly and efficently than one with direct genetic links which depends on selection for its expression."

**Eggs: 13; Generation: 12; Larvae: 1,2,13**

311. Leonard, D. E.
1972. **Survival in a gypsy moth population exposed to low winter temperatures.** Environ. Entomol. 1: 549–554.

"A population of *Porthetria dispar* (L.) exposed to low winter temperatures in Maine was examined to determine the amount of egg mortality and to determine the fate of the surviving population through one generation. Eggs protected by snow survived temperatures that reached −32.2°C (−26°F). The height above ground where egg masses were deposited was critical. A high percentage of egg masses (81 percent) was deposited below a height of 5 feet, but most hatch occurred in egg masses found below 1 foot. Egg mortality due to low temperature was 85 percent. An epizootic of nuclear-polyhedrosis virus further reduced the size of the subsequent population." The stand investigated was 83 percent *Populus tremuloides.* Cold treatment just prior to hatch increased larval mortality due to virus.

**Eggs: 12; Larvae: 5,7; Non-oak stands: 15**

312. Leonard, D. E.
1974. **Recent developments in ecology and control of the gypsy moth.** Annu. Rev. Entomol. 19: 197–229.

This article reviews pertinent literature since 1960.

**Review; Bibliography**

313. Lépiney, J. de
1928. **Insects harmful to cork oak within the forests of Morocco (second study)** [in French]. Ann. Epiphyt. 14(4): 313–321.

314. Lépiney, J. de.
1928. **Preliminary note on the role of ocellar vision on the behavior of larvae of *Lymantria dispar*** L. [in French]. Bull. Soc. Zool. Fr. 53: 479–490.

315. Lépiney, J. de.
1930. **A study of the biological complex of *Lymantria dispar*** [in French]. Mem. Soc. Sci. Nat. Maroc 23 (partial English transl. by H. J. MacAloney).

In the forests of Mamora and Zaers, where it is epidemic, gypsy moth hatch begins between mid-February and mid-April and lasts for 1 to 1½ months. Adult emergence is sometime between the end of April and the beginning of July. Larvae are attracted to silhouettes of erect, elongated forms, an example of visual perception with stemmata. Very young larvae are positively phototrophic, an orientation that disappears almost completely after the first feeding and becomes negative in older larvae. Young larvae cling constantly to the substrate, alternately resting and feeding. Older larvae are not bound by a dominant impulse to remain on the substrate; they react to variations in light and go into a diurnal resting stage in which they become torpid. The gypsy moth has long been present in the cork oak forests of Morocco. Five consecutive years of defoliation does not kill the cork oak, but defoliation does diminish or suppress the acorn crop, reduce the annual accretion of wood and cork, and make the cork difficult to remove by decreasing vasculary circulation. *Tenebroides maroccanus* and *Trogoderma versicolor,* predators of the gypsy moth in Morocco, have not been included in the biological complex of the gypsy moth elsewhere in the world.

**Generation: 3; Instars I–III: 13; Instars IV–VI: 13**

316. Lépiney, J. de.
1933. **The role of management of water and forests of Morocco and of the Institute of Scientific Research in the biological struggle against *Lymantria dispar* with the aid of *Schedius kuwanae*** [in French;]. 5th Congr. Int. Entomol., Paris, 1932. 5(2): 807–812.

317. Likventov, A. V.
1955. **Fertility, weight of eggs and survival of progeny of the gypsy moth** [in Russian]. Zool. Zh. 34: 1061–1065. (English transl. by computer and E. Alan Cameron).

Data on egg weight can be a very useful index for predicting vigor and density of future generations of the gypsy moth. As pupal size and weight increase, fecundity increases, and as fecundity increases, egg weight decreases. When eggs weigh 0.60 to 0.65 mg predominantly, the progeny are weak and reduced in number. When eggs weigh 0.80 to 0.90 mg predominantly, a population increase can be expected.

**Eggs: 2,13; Fecundity: 2,13; Pupae: 2,13**

318. Likventov, A. V.
1960. **The restraining effect of oak-linden stands on reproduction of the gypsy moth** [in Russian]. Tr. Vses. Inst. Zashch. Rast. 15: 33–40.

319. Linde, R. J. van der.
1967. **Studies on the populaton dynamics of *Euproctis chrysorrhea, Lymantria dispar* and *Malacosoma neustria* in relation to the ecology of the habitat** [in German]. 14th IUFRO-Kongress, 1967. München V., Sec. 24: 635–649.

320. Linde, R. J. van der.
1971. **The sailing flight of the young caterpillars of the gypsy moth (*Lymantria dispar* L.) and the influence of food plants on this phenomenon** [in German, English summary]. Z. Angew. Entomol. 67(3): 316–324.

Gypsy moth eggs were placed on small oak trees, and the trees were enclosed with wire mesh to study wind migration of the larvae. Mass movement occurred when the tree had not leafed out or when the tree was a nonpreferred species. The author estimated that the minimum wind velocity necessary for migration was around 1 m/sec.

**Instars I–III: 1,12**

321. Lipa, J. J.
1969. **Studies on *Arma custos* (Fabr.) (*Hemiptera: Pentatomidae*)** [in Polish, Russian and English summaries]. Pr. Nauk. Inst. Ochr. Rosl. II(1): 197–214.

*Arma custos* plays an important role in the control of the gypsy moth by preying on the larvae. "Adults overwinter in the litter and begin their activ[ity] at the end of April or in May. First clusters of eggs were observed in May, and maximum of oviposition took place in June and July. Total fecundity ranged up to 94 eggs. Development of eggs lasted an average of 10 days. Total development from egg to adult stage lasted from 35 to 75 days depending on temperature, food, etc. Adults and larvae of *A. custos* were effective predators. They killed and destroyed larvae, pupae, and eggs of several insects. A list of preyed insects as well as a list of plants on which *A. custos* was collected are included."

**Larvae: 3**

322. Littlefield, E. W., and S. H. Spurr.
1947. **Forest site conditions and the gypsy moth. Part III. The role of silviculture in maintaining conditions unfavorable to the gypsy moth. Harv. For. Bull. 22: 40–47.**

Massive outbreaks can be prevented by manipulating stand composition. Favored food species, such as oaks, gray birch, and poplar, should be thinned or removed. Replacement should be with conifers or defoliation-resistant hardwoods. In addition, the understory should be maintained to increase cover for predators.

**All stands: 15,18,19,20**

323. Liu, C. L.
1941. **Beginnings of a north China pest survey.** Peking Nat. Hist. Bull. 15(3): 225–234.

"*Lymantria dispar* var., a close relative of the notorious gypsy moth, was first discovered in an apricot orchard in the western hills and apparently limits its depredations to that host." There was heavy injury to apricot in Peking and Hopei regions. The pest survey was not intensive outside of the Peking area.

**Non-oak stands: 15**

324. Longworth, J. F., and J. C. Cunningham.
1968. **The activation of occult nuclear-polyhedrosis viruses by foreign nuclear polyhedra.** J. Invertebr. Pathol. 10: 361–367.

"A high mortality from nuclear polyhedrosis was recorded when larvae of *Aglais urticae* and *Porthetria dispar* were each fed the nuclear-polyhedrosis virus of the other species. The two viruses are morphologically and serologically distinct . . ." In *P. dispar*, larvae died 9 days after being fed homologous virus, and 87 percent were dead 18 days after infection. Controls (untreated larvae)

showed only 10 percent death by nuclear polyhedrosis.
**Larvae: 7**

325. Lozinskiy, V. A.
1930. **A note on the beetles of the genus *Calosoma* Web.** [in Ukrainian]. Kiev Ukr. Nauchno-Issled. Inst. Sakharnoi Prom. 1: 147–155.

326. Lozinskiy, V. A.
1957. **The small gypsy moth in the southern Ukrainian woodlands** [in Russian]. Zashch. Rast. Vred. Bolezn. 1: 51–52.

327. Lozinskiy, V. A.
1961. **On the correlation existing between the weight of pupae and the number and weight of eggs of *Lymantria dispar* L.** [in Russian, English summary]. Zool. Zh. 40(10): 1571–1573.
In investigations in 1959, female pupae of the gypsy moth were collected in July in mixed woodlands near Odessa in the Ukraine, where an outbreak of the moth was in its early stages. They were weighed, and the females that emerged were confined with males. After oviposition, the eggs were counted and weighed individually. The weight of the pupae was positively correlated with the number of eggs but not with egg weight, which is a variable depending on local ecological conditions and the phase of the nidus.
**Eggs: 13; Fecundity: 2, 13; Pupae: 13**

328. McManus, M. L.
1973. **A dispersal model for larvae of the gypsy moth, *Porthetria dispar* L.** Pages 129–138 *in* US/IBP Aerobiol. Program Handb., U. S. Int. Biol. Program.
Factors, that influence wind dispersal of first-instar larvae are light, temperature, humidity, and wind velocity. As temperature and humidity increase, the larvae ascend the tree at a faster rate. Larvae are also airborne longer under these conditions. Wind dispersal may be the reason for a sometimes poor correlation between egg masses per acre and population density.
**Instars I–III: 1, 12**

329. McManus, M. L.
1973. **The role of behavior in the dispersal of newly hatched gypsy moth larvae.** U. S. Dept. Agric. For. Serv., Res. Pap. NE-267. 10 p.
"Newly hatched gypsy moth larvae are morphologically and behaviorally adapted for airborne dispersal. The diel periodicity of both hatching and dispersal from the egg mass and photopositive behavior assure that larvae are in optimal position for dispersal when air turbulence is maximal at midday. The rate of larval activity depends upon ambient temperature and relative humidity ($R^2$ = 0.77). The larvae continually trailed silk and did not feed upon reaching the foliage. Rather, the larvae appeared predisposed to disperse and were readily dislodged by slight winds."
**Instars I–III: 1, 12**

330. Magnoler, A.
1968. **Laboratory and field experiments on the effectiveness of purified and non-purified nuclear polyhedral virus of *Lymantria dispar* L.** Entomophaga 13: 335–344.
Experiments showed nonpurified virus to have a greater efficacy than purified virus. This could be due to the presence of free virions, saprophytic flora, or toxic metabolites of saprophytic flora. Further experimentation is needed to determine the longevity of the increased virulence in the field.
**Larvae: 5, 7**

331. Magnoler, A. and A. Cambini.
1973. **Radial growth of cork oak and the effects of defoliation caused by larvae of *Lymantria dispar* L.** [in Portuguese, English and German summaries]. Bol. Inst. Prod. Flor. 35(4/3/9): 9–10, 53–59. (English transl. by U. S. Dep. Agric. For. Serv. Telecom GM-75-7179.)
The purpose of this work was to test the applicability of Duff's and Nolan's (1953) technique of series analysis of wood growth rings in establishing the effects of defoliation of cork oak (*Quercus suber* L.). Combined examination of the oblique and vertical series allows evaluation of the effects of the defoliation and discovery of the first year in which consequences of the damage occurred.
**Oak stands: 15, 24**

332. Majchrowicz, I. and W. G. Yendol.
1973. **Fungi isolated from the gypsy moth.** J. Econ. Entomol. 66: 823–824.
Gypsy moth lavae and pupae, dead from apparent mycoses, were collected from sites in Pennsyl-

vania, some of which had been previously sprayed with *Bacillus thuringiensis*. Eleven fungal species were isolated from 360 of the 1480 dead larvae and pupae. A greater proportion of specimens with fungal growth were from the sprayed sites. Species isolated were *Beauveria bassiana, Candida* sp., *Cladosporium, Paecilomyces farinosus, Paecilomyces* sp., *Penicillium frequentans, P. implicatum, P. cyaneo-fulvum, P. lanosum, P. citrinum, Aspergillus flavus, P. decumbens, P. notatum*, and *P. pulvillorum*. (*B. bossiana* and *P. faninosus* were isolated from over 80 percent of fungus-contaminated specimens.) An unidentified *Candida* was found on 42 percent of the egg masses; *P. farinosus* was on 23 percent. *P. farinosus* and *Candida* sp. were isolated most frequently from pupae and *P. farinosus* and *B. bassiana* were most frequent on larvae. Twenty-one fungal isolates were tested for pathogenicity. Only six were pathogenic to third-instar larvae, and not all isolates of the same fungus were equally pathogenic. *B. bassiana* produced 79.3 percent mortality; *P. farinosus*, 93 percent, 67 percent, and 74 percent (in different cultures); *Paecilomyces* sp. 63 percent; and *P. fumoso-roseus* 38 percent.
**Eggs: 8; Larvae: 8; Pupae: 8**

333. Maksimović, M.
1953. **Some observations about gradation crises of gypsy moths in plain and mountain forests in 1950** [in Serbo-Croatian, English summary]. Zast. Bilja 15: 12–27.

Two forest areas were compared: Crni Lug, a plains forest of *Quercus pedunculata*, and Istocna Boranja, a mountain forest of *Fagus sylvatica*. The plains forest averaged 17.8 egg masses per trunk, while the mountain forest averaged about 5 egg masses per trunk. The upper elevation limit for gypsy moths in this area was 850 m. Hatch in the mountain forest was as much as 4 weeks later than in the plains forest, depending on elevation. The mountain population suffered very high mortality in the first instar owing to low temperatures and rain. In the plains forest, high mortality was due to parasites of *Apanteles* spp. and tachinids. Overall, a gradient appeared from lower elevations to higher elevations. As elevation increased, biological control decreased and climatic control increased.
**Generation: 2, 4, 12**

334. Maksimović, M.
1954. **Numbers of eggs in the gypsy moth clusters in 1953** [in Serbo-Croatian, English summary]. Zast. Bilja 26: 1–4.

The number of eggs in a gypsy moth cluster reaches its maximum during progradation and its minimum during retrogradation. The average number of eggs during progradation is 2½ times that during retrogradation.
**Eggs: 2**

335. Maksimović, M.
1962. **The action of abiotic factors on the gypsy moth population in the forest Jakovački Ključ in 1958.** [transl. from Serbo-Croatian by M. Pantelic of Zast. Bilja 52–53: 37–44, 1959]. Off. Tech. Svc., U. S. Dep. Commer. OTS 60–21662.

The hatching of the gypsy moth can vary by 1 month from year to year. It was established that hatching of gypsy moth caterpillars begins when the average temperature of one 10-day period in the month is over 10.0 °C. High daily temperatures after hatching caused an acceleration of gypsy moth development in 1958. They then moved into a zone favorable for development and mortality resulting from the complex action of abiotic factors was minimal (10.6 percent in this study).
**Eggs: 12; Generation: 12; Larvae: 12**

336. Maksimović, M.
1958. **A contribution to the investigation of the numerousness of the gypsy moth by means of the trap method** [in Serbo-Croatian, English summary]. Zast. Bilja 49/50: 41–47.

Trapping males gives an indication of population density. Ten males caught in traps indicates 4 clusters/ha, which is a density approaching latency; 13 to 19 males indicates 7.1/ha, a light infestation. Critical density (18.6 to 27.6 egg clusters/ha) is indicated by 24 to 67 males. At this density the number is likely to increase rapidly in the following generation.
**Adults: 2, Eggs: 2**

337. Maksimović, M.
1958. **Some effects of the temperature upon diapause of the gypsy moth** [in Serbo-Croatian, English summary]. Zast. Bilja 41/42: 23–33.

Temperature was manipulated to test its influence on the diapause of the gypsy moth.
**Eggs: 12**

338. Maksimović, M. and M. Janković.
1960. **Some effects of abiotic factors in the forest Jakovački Ključ in 1959** [in Serbo-Croatian, English summary]. Zast. Bilja 56: 71–73.

Winter temperatures as low as −20°C in 1958–1959 did not affect the percentage of eggs hatching (86 to 100 percent). An increase in temperature reduced the average duration of larval development. Total preimaginal development varied under the influence of temperature maxima and minima. There was a tendency toward change in sex ratio favoring males as the duration of development decreased. As the duration of larval development increased, the average number of eggs laid by that generation of adult females increased. Larval mortality was highest when temperature minima were low.
**Eggs: 12; Fecundity: 12,13; Generation: 12; Larvae: 12,13; Sex ratio: 13**

339. Maksimović, M., M. Janković, and R. Marović.
1962. **Effect of abiotic factors upon the development of the gypsy moth in the locality of Jakovački Ključ in 1960** [in Serbo-Croatian, English summary]. Zast. Bilja 67/68: 113–124.

The absolute temperature minimum in the winter of 1959–1960 was −19.8°C, which reportedly had no effect upon the gypsy moth eggs. Hatching of controlled eggs occurred between April 1–21, with maximum hatching lasting 9 to 11 days. Low temperatures caused an extended period of larval development in both early- and late-hatching larvae. Average male development was 62.5 days, while female development was 72.6 days. Pupal development extended to 21.2 days for males and to 18 days for females in the first series (early hatches), and was of normal duration in the second series (late hatches). This was accounted for by the fact that the average developmental temperature was 20°C higher in the second series. The experimental adult life span was an average of 5 days, with a maximum of 10 days for males at an average temperature of 20.6°C for the first series, and 4.1 days' average with a maximum of 6 days for males of the second series. One female lived 11 days in the second series. The average number of eggs per cluster was 266 and 283, respectively, in series 1 and 2. It is stated that 45 to 48 percent of the total larval population in the forest can be presumed to have perished from the effects of temperature.
**Adults: 12; Eggs: 12; Fecundity: 12; Larvae: 12; Pupae: 12**

340. Maksimović, M.
1963. **Experimental research on the influence of temperature upon the development and the population dynamics of the gypsy moth** [transl. from Serbo-Croatian of Posebna Izd. Biol. Inst. N.R. Srb.-Beogr. 3, 1958.]. U.S. Dept. Agric. and Nat. Sci. Found. OTS 61-11203.

Research was done from 1950 to 1956 under controlled experimental conditions. Caterpillars were fed leaves from forest *Quercus pendunculata* Ehrh. Larval development at constant temperatures was shortest at 32°C: 25 days for males, 27 for females. The longest developmental period was at 16°C: 92 days for males, 97 days for females. The amplitude of variation in the duration of development decreased as the larvae grew older, showing the greater resistance of later instars. Development accelerated under variable temperatures, especially when nighttime minimums came close to the threshold temperature and the daytime temperature was favorable. Too great a difference between the high and low temperature retarded development as a result of physiological disruption. Development period of pronymphs and pupae at constant temperature decreased as temperature increased and was shorter for females. The maximum was at 16°C: 21 days for males, 17 for females. The shortest period, at 32°C, was 6 days for males, and 7 for females. The weight of male pupae raised at constant temperature was 24.5 to 39.4 percent of the female weight and was greatest below 20°C. Protogyny was observed at temperatures of about 16°C. and protandry at all higher observed temperatures. The life span of adult females under constant temperatures was longest at 16°C (11.7 days average) and decreased with an increase in temperature. Variable temperatures had a stimulating effect and lengthened life span. Fecundity declined with an increase in constant temperature: at 16°C the average number of eggs was 723.1, while at 32°C it was 275.5 eggs. The number of undeposited eggs in the ovarioles of the females increased with temperature. The number of unfertilized eggs was small, except at 32°C when it was 88

percent. The optimal fecundity was at variable or constant temperatures below 20°C. Newly hatched larvae endured starvation an average of 7 days at 20°C constant temperature and 100 percent relative humidity ($H_R$). Endurance declined with a decrease in $H_R$. Endurance increased with variable temperatures: at 11°C average there was no mortality for 8 days. Because of the great endurance of newly hatched larvae, starvation is probably not a normal factor of mortality under natural conditions. The gypsy moth is most sensitive to temperature at the embryonic stage. Exposure to −25°C during winter diapause killed an average of 20.9 percent after 1 day exposure, 61.4 percent after 2 days, 92.8 percent after 3 days, and 95.7 percent after 5 days. Eggs without hair on the cluster had 91 to 98 percent mortality after 1 day and 100 percent after 2 days at −25°C. There was greater sensitivity just before hatching: 20 minutes' exposure to −25°C caused 70 percent mortality, and 2 hours' exposure caused 100 percent mortality. The upper lethal limit at 80 and 100 percent $H_R$ was 37°C: at 20 percent $H_R$ it was 32°C. Below 20°C the $H_R$ was less important. Sexual index varied with temperature: At a constant temperature of 16°C it was 0.6; at 20.9°C it shifted to the benefit of males; from 28°C to 30°C it stayed the same; and at 32°C it was only 0.33. There were similar changes under variable temperature. It was concluded that there is an optimum temperature for reproduction.

**Adults: 1,2,13; Generation: 2**

341. Maksimović, M.

1965. **Sex attractant traps with female odor of the gypsy moth used for forecasting the increase of population of gypsy moth.** Page 398 *in* P. Freeman, ed., Proc. 12th Int. Congr. Entomol. 1964.

"The trap method used in Yugoslavia discloses the presence of very small numbers of gypsy moths and also serves for an uninterrupted study of change in population density. It is also possible to indicate critical density for best control results. The relationship between numbers of egg clusters and numbers of males caught in traps was established. The average number of egg clusters to every 25 males caught was 10/ha, while for 26 to 100 males it may go up from 10 to 100/ha, which is the critical number. Results are given of the application of this method in an area with almost no control measures; these are compared with results obtained in areas where the trap method was applied together with introduction of control of critical numbers."

**Adults: 1,2,13; Generation: 2**

342. Maksimović, M.

1969. **Investigation of population dynamics of the gypsy moth by means of traps.** Pages 9–19 *in* E. Doyle, ed. Insect ecology and the sterile male technique. Proc. FAO/IAEA Div. At. Energy Food Agric., 1967, Vienna.

"The use in Yugoslavia from 1957 to 1964 of traps containing the sexual odor of the gypsy moth made it possible to study the population dynamics of the insect. The method was used in the wooded areas of three republics, Serbia, Bosnia and Herzegovina, and Croatia. The efficiency of the traps was also investigated. Thus, the *critical* number of males caught in a trap was determined and compared with the *critical* number of egg clusters per unit area. During the observation period, a percentage of traps with the *critical* number of males was found in Serbia. The smallest number of such focal points (4.2 percent) was recorded in the lowest population period. This increased to 51.1 percent in the pre-peak year (1964) of the cycle. The existence of the focal points and the variations in numbers during the lowest population period shows that this period does not appear everywhere at the same time. The traps showed various changes in the numbers of the insect in different ecological conditions, as a result of various factors that restrict or accelerate propagation. It was learned by using the traps that the smallest population density is not found in areas larger than a single wood, and even within a single wood the density varies. By establishing the ecologically unsuitable places for gypsy moths, the traps made it possible to investigate the factors that make the existence of the insect possible. . . . . The use of the trap method gave a clear insight into the need for control during the lowest population period. This was hitherto not recognized, and control measures were not taken. It has now been realized that the gypsy moth should be destroyed in the initial focal points."

**Generation: 2,12**

343. Maksimović, M., and I. Politeo.

1970. **A contribution to the biology of the gypsy moth on the island Hvar** [in Serbo-Croatian, English summary]. Zast. Bilja 21(108): 119–130.

Two areas of gypsy moth infestation on the island Hvar were compared because of the difference in stand composition. Jelsa Park contained *Populus pyramidalis, P. alba, Quercus ilex, Robinia pseudoacacia,* and *Salix babylonica*—all food species of the gypsy moth. The only known host plants of Vrba Park were a few *Q. ilex* and *P. tremulae.* In Jelsa, egg masses were found exclusively on *Populus* spp., while in Vrba egg masses were found on *Pinus halepinsis* and *Tamarix gallica.* During 2 years of population increase, the number of eggs per egg mass decreased twice as much in the preferred habitat of Jelsa. Hatching started 7 days later in Vrba Park, and pupation occurred about 15 days later.

**Eggs: 2; Generation: 2,12**

344. Maksimović, M., P. Bjegović, and L. Vasiljević.

1970. **Maintaining the density of the gypsy moth enemies as a method of biological control** [in Serbo-Croatian, English summary]. Zast. Bilja 21(107): 3–15.

The population density of the gypsy moth differs from year to year, with an outbreak every 7 to 9 years in Yugoslavia. During latency, natural enemies of the gypsy moth do not have enough hosts to maintain their population density and their numbers decline. The theory of integrated control is that the gypsy moth can be kept at a level sufficient to maintain its natural enemies which in turn will keep the gypsy moth in check for periods longer than 7 to 9 years. During spring, in the years 1964 to 1967, gypsy moth eggs were introduced into test plots which were subsequently compared with control plots for number of egg masses, number of eggs in each mass, egg parasites, sterile eggs, larval parasites, and degree of defoliation. The percentage of parasitization of the eggs did not vary significantly between test and control sites. Neither the number of eggs per mass nor the number of sterile eggs was an important factor in population reduction. *Apanteles porthetriae* Mues., parasite of young larvae, built up within 4 years and was an important control factor. From the results of this work, it appears that the gypsy moth gradation and resultant defoliation were prevented by the introduction of eggs. The parasites exerted a radial influence on gypsy moth population density, with lessening influence as the distance from the center of the introduction of eggs increased.

**Eggs: 4; Generation: 2; Instars I–III: 4; Non-oak stands: 15**

345. Maksimović, M., P. Bjegović, and L. Vasiljević.

1972. **Feeding and maintaining the density of the gypsy moth's enemies as a method of biological control.** Page 57, v. 3 Proc. 13th Int. Congr. Entomol., 1968. Nauk Leningrad.

For 4 years eggs were collected from areas of Yugoslavia where the gypsy moth gradation was at a peak. They were introduced to regions with light infestations to be used as food by the natural enemies of the gypsy moth. In a *Platanus occidentalis* forest in Macedonia there was a base population of 100 egg clusters/ha in 1964, to which 21 kg of eggs were added. That year many larvae developed, and there was heavy defoliation. In the next 3 years, 55 kg, 20 kg, and 14 kg of eggs were added, respectively, but the damage was slight. In a control forest 3 km from the first, the gypsy moth was near latency in 1964 and 1965, caused visible damage in 1966, and completely defoliated willow and partially defoliated *P. occidentalis* in 1967. That last autumn 422.2 egg clusters/ha were observed. *Ooencyrtus kuwanae* How. and *Anastatus disparis* R., parasitized 25 to 31.1 percent of the eggs in the test site, showing that egg parasites play an important regulatory role. *Apanteles porthetriae* Mues. was the dominant parasite: 5702 cocoons/ha were observed on the test site and 2151/ha on the control site. An increase in gypsy moth numbers can be prevented by keeping natural enemy numbers at a high level when the gypsy moth itself is at a low density level.

**Eggs: 4; Instars I–III: 4; Generation: 2; Non-oak stands: 15**

346. Malozemov, Y. A.

1962. **Developmental characteristics of foci of gypsy moths *(Porthetria dispar)* in the Il'men Game Reservation** [in Russian]. Pages 104–106 *in* B. P. Kolesnikov et al., eds. Dokl. Nauchno-Tekh. Konf. Molodykh Spets. Lesn. Proizvod. Urala Itogam Rab. 2nd, 1961. Sverdlovsk.

347. Manon.
1926. **Notes on *Liparis dispar* L. and on some of its varieties** [in French]. Rev. Zool. Agric. Appl. 25: 25: 39–42, 49–55.

348. Marcou, G., and I. Catrina.
1962. **Experimental research on the causes of dieback of oak in Rumania** [in French]. Proc. 13th IFRON Congr., Vienna, 1961, Part D, Sec. 24/13.

349. Marcu, O.
1971. **Gypsy moth egg weight — an important prediction index** [in German, Rumanian and English summaries]. Brasov Rum. Inst. Politeh. Bul. Ser. B. Econ. For. 13: 111–118.

"There is a direct correlation between the mean weight of the eggs (mean value of the weight of 100 eggs) and the number of eggs laid, the percentage of hatching, the length of the newly hatched, famished insects' life, the weight of [the] pupae, and the fecundity of the adults of the next generation. The mean weight of the eggs, an easily ascertainable value, is therefore of great practical importance, indicating the percentage of hatching and the length of the larva's life, especially in a spring season with unfavorable conditions. These indications may help in correcting the population density and in avoiding the disagreement between the predicted level of damage and the real damages, and in some cases they may lead to cancellation of control measures."
**Eggs: 2, 13**

350. Marcu, O.
1972. **The influence of nutrition on the gypsy moth and its practical importance** [in Rumanian, German summary]. Brasov Rum. Inst. Politeh. Bul., Ser. B. Econ. For. 14: 171–178.

351. Marcu, O.
1972. **Research on the most important parasites of the gypsy moth** [in Rumanian, German summary]. Brasov Rum. Inst. Politeh. Bul., Ser. B. Econ. For. 14: 179–188.

352. Marović, R.
1971. **A study of the effect of low winter temperature on gypsy moth eggs *(Lymantria dispar)*.** Zast. Bilja 22(115/116): 369–376.

"Under laboratory conditions, a constant temperature of −25°C in February brings about mortality of gypsy moth caterpillars in eggs. The effect is more pronounced when the eggs (whether deprived of hairs or in egg masses) are transferred directly from insectarium to −25°C than if they are preliminarily acclimatized at −6°C for 6 days. Eggs deprived of hairs are more susceptible than egg masses, but with a longer exposure, the protective effect of the hairs is not enough to prevent total mortality. In the field, winter temperatures of −21°C did not cause the death of egg masses. On the basis of laboratory investigations, it may be said that the caterpillars in eggs in the field can tolerate winter lows of −25°C for 3 to 4 days without increased mortality. It is possible that at higher altitude and in microhabitats where the temperature drops below −30°C, these minima reduce the gypsy moth. This should be the subject of further research."
**Eggs: 12**

353. Martelli, M., and M. A. Giovanni.
1958. **Preliminary research on insects of cork oak *(Quercus suber* L.) in Sardinia** [in Italian, English summary]. Boll. Zool. Agrar. Bachic. Ser. 2.2(1): 5–49.

Thirty-three phytophagous insects (1 Isoptera, 11 Hemiptera, 7 Lepidoptera, 2 Diptera, 3 Coleoptera, 9 Hymenoptera) and 53 symbionts of them (7 Diptera, 3 Coleoptera, 43 Hymenoptera) were observed on cork oak during 3 years of research. Those insects (*Lymantria dispar* L. and *Malacosoma neustrium* L.) presenting greater danger to the tree were studied more intensively.
**Oak stands: 15**

354. Masaki, S.
1956. **The effect of temperature on the termination of diapause in the eggs of *Lymantria dispar* Linne.** Oyo Dobutsugaku Zasshi 21(4): 148–157.

Experiments were performed to determine the range of temperature and the length of exposure to cold required for gypsy moth eggs to complete diapause. "When the eggs were subjected to a low temperature of 5°C for different periods and then incubated, the percentage hatch was increased, the mean hatching time after removal to high temperature was shortened, and the degree of [its] variability was reduced — all in proportion to the duration of exposure to the low temperature. The optimal temperature for the completion of diapause lies between 5 and 12°C, and the upper and

lower thresholds are about 20 and 0°C, respectively. There was no evidence indicating a clear-cut distinction between the diapause and postdiapause stage, and the larvae within the egg shell became competent to hatch gradually."
**Eggs: 12, 13**

355. Masner, L.
1958. **A new egg parasite of gypsy moth, *Lymantria dispar* (L.).** Entomophaga 3: 39–44.
Five *Hadronotus lymantria* n.sp. (Scelionidae: Scelioninae) were reared from eggs of the gypsy moth in East Slovakia. It is described as a new species. It is the third scelionid known to parasitize gypsy moth eggs. The others are *H. howardi* Mokr. et. Ogl., reported to infest 75 to 85 percent of eggs in the Crimea, and *Telenomus phalaenarum* Nees. A morphological key is given to differentiate between the three species.
**Eggs: 4**

356. Masson, J.
1970. **Four species of tachinids bred from a rearing of *Lymantria dispar* caterpillars in the laboratory** [in French, English summary]. Ann. Fac. Sci. Marseilles 43B: 51–61.
The following tachinids emerged from *Lymantria dispar* pupae reared in the laboratory: *Compsilura concinnata* Meig., *Drino inconspicua* Meig., *Eucarcelia separata* Rond., and *Exorista larvarum* L. Of these, *E. separata* is considered a rare parasite of *L. dispar*.
**Larvae: 4; Pupae: 4**

357. Menzel, R.
1923. **The occurrence of a very useful parasitic fly (*Compsilura concinnata* Meig.) in java** [in Dutch]. De Thee 4:89–90.

358. Mercet, R. G.
1918. **Parasites of *Liparis dispar*** [in Spanish]. Rev. Montes, Madrid 42(1004): 775–781.

359. Mercet, R. G.
1923. **Chalcids parasitizing lepidopteran larvae** [in Spanish]. Rev. Fitopatol. 1(1): 12–19.

360. Mercet, R. G.
1926. **A new parasite of *Porthetria dispar*** [in Spanish]. Rev. Fitopatol. 2–3: 48–50.

361. Merker, E.
1960. **The influence of tree condition on the mass increase of some forest pests** [in German, English summary]. Z. Angew. Entomol. 46(4): 432–445.
Changes in soil have an influence on the trees and thus upon the gradations of insect pests in the forest. For instance, both the amount of water in the soil and its fertility contribute to lowering the populations of harmful insects. Fertilized soil is capable of decimating dangerous forest insects. Populations of larvae of *Lymantria monacha* L. and *L. dispar* L. have had a mortality of 50 to 80 percent after the plants have been fertilized with calcium carbonate and ammonium nitrate.
**All stands: 15, 23, 24**

362. Merker, E.
1964. **The effect of food on the development of *Lymantria dispar*** [in German]. Allg. Forst Jagdztg. 135(2): 34–36.

363. Miao, C. P.
1939. **Study of some forest insects of Nanking and its vicinity.** III: Observations on the gypsy moth (*Porthetria dispar* L.) Contrib. Biol. Lab. Sci. Soc. China. Zool. Ser 13(5): 57–77.
The gypsy moth is widely distributed in China. Food plants in the vicinity of Nanking (32° N, 118° E) are *Prunus persica* Stokes, *P. salicina* Lindley, *P. pseudocerassus* Hance, *Liquidambar formosana* Hance, *Quercus fabri* Hance, *Q. acutissima* Carriere, *Q. aliena* Blume, *Q. serrata* Thunberg, and *Q. glauca* Thunberg. A morphological description of each life stage is given. There are four larval molts prior to pupation, with a total larval period of 43 to 60 days. Newly hatched larvae rest on the egg cluster 1 + days, begin to eat leaf hairs, then to make holes in the leaf. They feed little on rainy days. Instead, they cling to the underside of the leaf or suspend themselves on a short thread. In good weather, they feed day and night, become very active, and hang on a long silk thread when disturbed. After feeding for 6 days, they rest 1 to 2 days before molting. Feeding resumes after the molt when the head becomes black. They have an irregular feeding pattern. Third- and fourth-instar larvae feed on the edge of a leaf or eat through it. Older larvae eat from the edge without boring through the leaf. They rest before spinning a silky, flimsy cocoon which is at-

tached to a tree trunk or between two leaves. The prepupal period is 1 to 3 days. They pupate May 15–June 7 for about 2 weeks. Imago emergence is primarily June 4–8. The female is unable to fly except when disturbed. Copulation is soon after emergence; eggs are laid (June 9–12) on any fixed object, expecially under branches. They emerge March 31–April 10.

**Adults: 1; All stands: 15; Eggs: 2; Instars I–III: 1; Instars IV–VI: 1; Prepupae: 1**

364. Mihalache, G. H., and I. Wagner.
1964. **A contribution to the study of the characteristics of the egg parasites of *Lymantria dispar* L. by means of the parasite *Anastatus disparis* Ruschka** [in Rumanian]. Rev. Padurilor 79(2): 79–82.

365. Mikkola, K.
1971. **The migratory habit of *Lymantria dispar* (Lepidoptora: Lymantriidae) adults of continental Eurasia in the light of a flight to Finland.** Acta Entomol. Fenn 28: 107–120.

Nine male gypsy moths were collected in Finland in 1958 and by their appearance were inferred to be of southeastern Russian origin. Migration was attributed to a warm air current from the southeast. The same migration had been observed 3 days earlier near Moscow as an unusual mass flight of both males and females. "According to a trajectory analysis, the moths had migrated intermittently, advancing with the warm front and/or flying chiefly by night." It was concluded that the continental summer drought was a major factor contributing to the evolution of the migratory habit in adult gypsy moths. It may affect the environment of the gypsy moth larvae in at least two ways: The defoliation caused by the caterpillars in spring and early summer is probably harder on the trees because of summer drought, and the quality of the food will vary with the intensity of the drought.

**Adults: 1, 12; Larvae: 12**

366. Minott, C. W.
1922. **The gipsy moth on cranberry bogs.** U. S. Dep. Agric. Bull. 1093. 19 p.

"Infestations of gypsy moths in cranberry bogs are due principally to wind dispersion of first-stage larvae, which occurs only when conditions of wind velocity and temperature are favorable. The time when maximum dispersion prevails is usually not longer than from 2 to 5 days. Because of the activity of the young caterpillars in seeking food, there are two daily periods of maximum dispersion, between 9 a.m. and 12 noon and between 2 and 5 p.m. Mortality of first-stage larvae is very great—large numbers perish from low temperatures, unfavorable food, predaceous insects, and disease. The embryos in all gypsy moth eggs deposited on cranberry bogs are killed by winter flowage, when the bogs are flowed from December 1 to May 1. Upon deciduous foliage in general, the feeding of the first-stage larvae is upon the leaf hairs, but the injury to cranberry plants is caused by feeding upon the terminal buds, and later upon the new growth. As a rule, vines recover more quickly from injury in wet bogs than in dry ones. Flooding is the most effective method of control in wet bogs, but spraying is the only method that can be employed in dry bogs."

**All stands: 15; Generation: 1; Instars I–III: 1, 12**

367. Minott, C. W., and I. T. Guild.
1925. **Some results of the defoliation of trees.** J. Econ. Entomol. 18: 345–348.

Decrease in growth with an increase in defoliation was found to be a linear relationship. Over a 10-year period, a one-third loss of foliage resulted in a one-third decrease in growth. Susceptibility to defoliation varied among individuals of a species. Most white oaks die after two, three, or four complete defoliations; however, one individual remained in good condition after five defoliations.

**Oak stands: 19, 24, 25**

368. Mirković, D. and V. Miščević.
1960. **Influence of the browse of gypsy moth (*Lymantria dispar* L.) upon the accretion of oak trees** (in Serbo-Croatian, English summary]. Zast. Bilja 60: 3–19.

The annual growth of 254 trees in an oak wood at Jacovački Ključ was measured from 1945 to 1959. During this time there were two gypsy moth gradations (1946–1950, 1953–1957). Accretion in cubic capacity declined considerably during the years of the gradation, with minimum growth in 1957, the year of maximum average number of larvae per tree. When the arithmetic mean of the accretion during the 1953–1957 gradation is compared with that during latency, the losses amount to 18.1 per-

cent. When average accretion during the gradation is compared with the average of the trend of the accretion for the same period, the deficit is 49.4 percent. The average accretion during the gradation compared with the highest value of accretion prior to the gradation shows a 39.0 percent deficit. This last result is ". . .taken as the most probable, and it tallies with the results of other investigators utilizing different methods." The correlation between growth and climatic factors decreased considerably during the gradation. The negative influence of the gradation overcame the existing positive influence of climatic factors.
**Oak stands: 15, 24; Generation: 2**

369. Mizuta, K.
1960. **Effect of individual number on the development and survival of the larvae of two lymantriid species living in aggregation and in scattering** [in Japanese, English summary]. Nippon Oyo Dobutsu Konchu Gakkai-Shi 4(3): 146–152.
Gypsy moth larvae were reared with 1, 2, 5, 10, and 20 individuals per vessel at temperatures of 23 to 27° C and natural light conditions. "In every culture all the larvae developed successfully." As the number of larvae per vessel increased, larval and pupal durations, pupal weight, and fecundity decreased; the overcrowding had an adverse effect on the development of the gypsy moth.
**Fecundity: 2; Larvae: 2; Pupae: 2**

370. Mizuta, K.
1971. **Synchronized hatching of some lepidopterous insects.** Saijo Hiroshima Agric. Coll. Bull. 4(2): 91–96.
Laboratory experiments examined the effect of the egg mass on the rate of hatching of four species of Lymantriidae: three species of *Euproctis* and *Porthetria dispar japonica* Motschulsky. The hatching curves of the *Euproctis* showed a different pattern for isolated eggs and for egg masses, with more rapid and synchronized hatching in the egg masses. There was no significant acceleration in hatching of *P. dispar japonica* in egg masses. All species studies showed a diurnal rhythm of hatching. It is believed that hatching is synchronized by the behavior of the hatchlings. Newly hatched larvae crawled to the surface of the egg mass and nibbled at egg shells from which larvae had not yet emerged. Isolated individuals seemed to have difficulty getting out of the egg shell alone. It was not understood why *P. dispar japonica* did not show different hatching curves for isolated eggs and for egg masses, except that their larvae disperse just after completing hatching, in contrast to *Euproctis* larvae which aggregate.
**Eggs: 1; Instars I–III: 1**

371. Mokrzecki, Z., and A. A. Ogloblin.
1931. ***Hadronotus howardi* n. sp. (Microhymenoptera, Proctotrupidae).** Pol. Pismo Entomol. 10(1): 1–8.
This contains the morphological description of a new egg parasite, *Hadronotus howardi* n. sp., which in the Crimea has been observed to annihilate 75 to 85 percent of gypsy moth eggs.
**Eggs: 4**

372. Molis, S.
1970. **Some data on the biology of *Ocneria dispar* L. in South Lithuania** [in Lithuanian, English summary]. Acta Entomol. Litu. 1: 91–98.
"*Ocneria dispar* is a rather infrequent insect species in Lithuania, though during its massive propagation in the south of the Soviet Union (occurring after drought every 6 to 11 years)" it is carried by wind to southern Lithuania. A massive outbreak was registered in 1956. Data are presented based on investigations in southern Lithuania from 1959 to 1967. Pupae, moths, and fresh eggs "were detected in the orchards of the area (the town Kapsukas) on the 20th of June 1959." Moths fly and lay eggs from July to the middle of August. There are 256 to 386 eggs in one oviposition. "At the end of April or the beginning of May, dark, hairy larvae emerge . . ." and in 3 to 4 days, they begin crawling "in all directions searching for food and often are carried by the wind to great distances." The larvae are polyphagous. Within 30 to 40 days, males moult four times and females five times. After 3 to 4 weeks they emerge as moths. Natural enemies of *Ocneria dispar* are cuckoos, woodpeckers, blue titmice, and thrushes. The egg parasites, *Telenomus laevisculus* Ratz. and *Oenocyrtus tardus* Ratz. kill up to 10 percent of the eggs. The larvae are infected by the parasitic flies *Phorocera silvestris* R.-D. and *Blepharipoda scutellata* R.-D. In the climatic conditions of Lithuania up to 22 percent of the larvae are killed by these flies.
**Generation: 1, 4, 9**

373. Monastero, S.
1955. **The forests of Ficuzza threatened by the gypsy moth (*Lymantria dispar* L.)** [in Italian]. Boll. Ist. Entomol. Agrar. Oss. Fitopatol. Palermo 1: 167–174.

374. Moravskaia, A. S.
1958. **The gypsy moth is a pest of the forest and plantings** [in Russian]. Priroda (Moskow) 3: 90–93.

375. Moravskaia, A. S.
1973. **Influence of imaginal feeding on fecundity and life duration of adults in *Anastatus disparis* (Hymenoptera: Eupelmidae), egg parasite of the gypsy moth** [in Russian, English summary]. Zool. Zh. 52(12): 1809–1814.

In the experiment without imaginal feeding, the maximal life span of males was 5 days and of females 7 days. When insects were fed on sugar syrup, the maximal life span of males increased to 16 days, and that of females increased to 32 days; the maximal number of eggs matured in one female was nine. When they were fed both carbohydrates and host egg contents (as occurs in nature), the number of matured eggs reached 16. The maximal life span of females was 33 days. "To determine the effectiveness of *Anastatus,* one has to consider not only the number of eggs infested by the parasite but also [the number of eggs lost] as a result of pricking by a female for feeding on its contents. One female can exterminate, without subsequent infestation, up to 24 eggs of the gypsy moth."

**Eggs: 4**

376. Moravskaia, A. S.
1973. **A new additional host of *Anastatus disparis* (Hymenoptera: Eupelmidae), egg parasite of *Porthetria dispar*** [in Russian, English summary]. Zool. Zh. 52(1): 147–150.

"*Anastatus disparis* Rusch., a specific parasite of *Porthetria dispar* L., develops synchronously with its host. In the Tellermanovsky forest region of the Voronezh District, *A. disparis* develops mainly in the eggs of *P. dispar,* but it was reared from the eggs of *Palomena prasina* L. as well. *A. disparis* infests the eggs of *P. prasina* both in nature and under artificial conditions. In the eggs of *P. prasina, A. disparis* has the second additional generation during a year. Both males and females of *A. disparis* were reared from the eggs of *P. prasina.*"

**Eggs: 4**

377. Morgan, P.
1972. **Devastation of northeastern forests by the gypsy moth.** Northern Nut Growers Assoc. Annu. Rep. 63: 56–58.

From 1969 to 1971 on the Newark, N.J. watershed, more than 1,052,000 oaks and 47,000 hemlocks and pines died from gypsy moth activity. In 1971, dead oaks averaged 60 trees per acre, with white oaks suffering up to 80 percent mortality (tabulated from 18,000 acres). A survey taken in the New Jersey National Historical Park in 1970 showed that 10,000 oak trees had been killed by defoliation. This constitutes 33 percent of the park's oak forest.

**All stands: 15,25,26**

378. Mosbacher, G. C.
1967. **On the influence of temperature on the degree of intersexuality in *Lymantria dispar* L.** [in German]. Zool. Anz. 30 Suppl.: 509–521.

**379. Mosbacher, G. C.**
**1968. A mutant of *Lymantria dispar* L. with abnormal wing form and its temperature dependence in manifestation** [in German, English summary]. Genetica 39: 25–40. The Hague, Netherlands.

"The mutant *Incisiva* (*Ic*), found in a German population of *Lymantria dispar* L., is characterized by a semicircular to parabolic incision on the tips of the hindwings (occasionally on the forewing also). The inheritance of this character is dominant, autosomal, and presumably monofactorial. Penetrance and expressivity of the *Incisiva* allele are strongly temperature-dependent. As a rule, the penetrance increases with decreasing temperatures from 0 percent in 27°C cultures to 100 percent in 16°C cultures. Modifying genes, which are partly sex-linked, can considerably decrease the penetrance of the gene in cold-cultured individuals. At low temperatures, incisions are often observed even on the tips of the forewings. In this case, the hindwings are split up to the base, thus displacing or even suppressing the radial and median veins. The size of incisions and their oc-

currence in forewings is influenced by the genetic background. The temperature-sensitive period for *Ic* mutant manifestation was determined to be in the last two instars before pupation, i.e., in the fourth in males, and in the fifth in females. This temperature-sensitive phase coincides with the initial stages of development of the presumptive wing blade in the imaginal disc. The wing incision is recognizable as a split even before the main growth period of the wing blade at the beginning of the last larval instar."
**Adults: 12,13**

380. Mosher, F. H., and R. T. Webber.
1914. **The relation of variation in the number of larval stages to sex development in the gypsy moth.** J. Econ. Entomol. 7: 368–373.
In controlled laboratory experiments, it was found that those larvae that pupated in the fifth stage produced male moths, while those having a sixth stage developed into females.
**Larvae: 13**

381. Mosher, F. H.
1915. **Food plants of the gipsy moth in America.** U.S. Dep. Agric. Bull. 250. 39p.
Results of laboratory experiments to determine food preferences are given. Newly hatched larvae were put in trays with one food type. If all died, then a new trial was begun at the stage prior to the one at which the previous trial was discontinued. Food classes were based on number of larvae dying in laboratory trials and on field observations. The report concludes that white oak is probably the most favored food plant.
**All stands: 15; Larvae: 12**

382. Moucha, J.
1957. **On the influence of food in the development of the gypsy moth *(Lymantria dispar* L.)** [in Czechoslovakian, Russian and German summaries]. Cas. Cesk. Spolecnosti Entomol. 54(1): 73–80.

383. Muesebeck, C. F. W.
1927. **New species of chalcid flies parasitic on the gipsy moth parasite, *Apanteles melanoscelus* (Ratzeburg).** J. Agric. Res. 34: 331–333.
Three new parasites of *Apanteles melanoscelus* (*Coelopisthia scutellata* n. sp., *Hypopteromalus nimicus* n. sp., and *Dimmockia pallipes* n. sp.), which were found to be significant in reducing the activity of *A. melanoscelus,* are described.
**Larvae: 4**

384. Musebeck, C. F. W., and S. M. Dohanan.
1927. **A study in hyperparasitism with particular reference to the parasites of *Apanteles melanoscelus* (Ratzeburg).** U. S. Dep. Agric. Bull. 1487. 35 p.
Hyperparasites are generally less discriminating than primary parasites regarding host selection. They can easily adapt to a new host or to the absence of a host. When the primary parasite is protected by a cocoon or puparium, the hyperparasite is generally an external feeder. All observed parasites of *Apanteles melanoscelus* (Ratzeburg) are parthenogenic. *A. melanoscelus* is a solitary parasite of the gypsy moth, also sometimes reared from *Hemerocampa leucostigma.* Adults appear in May right after gypsy moth eggs hatch. They oviposit in first-instar larvae; larval development is in 18 to 20 days. They emerge from second and third instars to form their cocoons. Adults emerge 1 week later, mate, and oviposit in third-instar larvae. They develop in gypsy moths in 16 to 20 days, and cocoons appear in early July. They overwinter as mature larvae in cocoons on trees. Over a 3-year period, 28 percent of first generation *Apanteles* cocoons produced *Apanteles,* 53 percent produced hyperparasites, and 19 percent produced neither. The length of time the cocoon is exposed determines survival in the second generation: Probably no more than 0.5 percent of cocoons formed in July produce *Apanteles* the next spring, and close to 50 percent produce neither parasite nor hyperparasite. This is because of excessive hyperparasitism and because adult hyperparasites feed at oviposition holes, often without depositing eggs. Thirty-five species were reared from *Apanteles* cocoons; 14 species from 90 percent. They are listed in order of importance: *Eurytoma appendigaster* (Swed.), *Dibrachys boucheanus* (Ratz.), *Hemiteles tenellus* (Say), *Dimmockia incongruus* (Ashm.), *Gelis bucculatricis* (Ashm.), *G. apantelis* Cush., *Eupelmus spongipartus* Foerst., *Hypopteromalus tabacum* Fitch, *Habrocytus dux* Girault, *Hemiteles fulvipes* Grav., *Eupilminus saltator* (Lindm.), *Dimmockia pallipes* Mues., *Pleurotropis tarsalis* (Ashm.), and *P. nawaii* (Ashm.). The vast majority of hyper-

parasites are Hymenoptera in the families Ichneumonidae and Chalcidoidea.
**Instars I–III: 4**

385. Muesebeck, C. F. W.
1928. **A new European species of *Apanteles* parasitic on the gipsy moth.** Proc. Entomol. Soc. Wash. 30(1): 8–9.

*Apanteles porthetriae* is widely distributed in Europe but seems to have been frequently confused with *A. vitripennis* Haliday and occasionally with *A. Lateralis* Haliday and *A. solitarius* Ratzeburg. The species is named and described here. The type locality is Olaszliszka, Hungary; its type, allotype, and six paratypes are located in the U.S. National Museum.
**Instars I–III: 4**

386. Muescbeck, C. F. W.
1931. ***Monodontomerus aereus* Walker, both a primary and secondary parasite of the brown-tail moth and the gipsy moth.** J. Agric. Res. 43: 445–460.

The adult female of *Monodontomerus aereus* oviposts about the first of June. From one to four eggs are deposited during one insertion of the ovipositor. These are usually placed externally on the host within the cocoon, puparium, or pupae, but when oviposition occurs in living lepidopterous pupae or very fresh tachinid puparia, the eggs are deposited internally. "*Monodontomerus aereus* has been reared as a direct hyperparasite from cocoons or puparia of many primary parasites of the gipsy moth and the brown-tail moth. It has also been obtained from the pupae of certain Lepidoptera, and in these cases has sometimes been a primary and sometimes a secondary parasite."
**Larvae: 4; Pupae: 4**

387. Muesebeck, C. F. W., and D. L. Parker.
1933. ***Hyposoter disparis* Viereck, an introduced ichneumonid parasite of the gipsy moth.** J. Agric. Res. 46: 335–347.

"*Hyposoter disparis* has, on rare occasions, been observed to be a very abundant parasite of the gipsy moth in Europe, but it has not yet become an important control agent of that pest in New England. Apparently the parasitism is heavier in dense woodland than in open growth or on the outer edges of wooded areas. The potential effectiveness of the species as a parasite of the gipsy moth is offset to a considerable extent by failure of eggs to hatch or by early death of the parasitic larvae. From 10 [percent] to more than 30 percent of eggs and young larvae of the parasite dissected from host caterpillars that had been attacked in the laboratory and in the field were found to be dead and surrounded by phagocytes of the host. This suggests incomplete adaptation of the parasite to this host."
**Larvae: 4**

388. Munro. W.
1917. **Management of typical woodlots infested with the gipsy moth in the white-pine region.** Pages 17–49 *in* Control of the gipsy moth by forest management. U.S. Dep. Agric. Bull. 484.

Eighteen species of food plants are potentially controlling factors in management of the gypsy moth, owing to their silvicultural characteristics. Broken down by preference classes there are: Class I (species favored by larvae in all stages): *Populus tremuloides* and *P. grandidentata* (aspens), *Fagus atropunicea* (beech), *Betula populifolia* (gray birch), and the oaks *Quercus pumila, Q. velutena, Q. rubra, Q. coccinea,* and *Q. alba.* Class II (species favored by later instars): *Castanea dentata* (chestnut) *Tsuga canadensis* (hemlock), *Pinus rigida,* and *P. strobus* (pines). Class III (not favored, but a small proportion of moths may feed): *Acer rubrum* and *A. saccharum* (maples). Class IV (unfavored): *Fraxinus americana* (ash), *Juniperus virginiana* (red cedar), and *Chamaecyparis thyoides* (white cedar). The author proposes management techniques based on the proportion of each class in the stand.
**All stands: 19; Larve 1**

389. Nagaraja, H., P. R. Dharmadhikari, and V. P. Rao.
1968. **A comparative study of the external morphology of *Lymantria obfuscata* Wlk.** in India and *L. dispar* L. in the U.S.A. Bull. Entomol. Res. 59:105–112.

Morphological differences between *Lymantria obfuscata* and *L. dispar* and considered by U.S. Department of Agriculture lepidopterists to be small and trivial in an evolutionary sense. Perhaps the taxonomy should be reviewed if the two species are not shown to differ serologically. They are very similar biologically and have common or closely related parasites. The *Lymantria* species in the northwest Himalayas has been confirmed as *L.*

*obfuscata.* The habitat overlaps with the southern range of *L. dispar.*
**Generation: 12**

390. Nagasawa, Sumio.
1965. **On the number of larval moults in the "Takamatsu" race of the gypsy moth, *Lymantria dispar* L.** [in Japanese]. Nippon Oyo Dobutsu Konchu Gakkai-Shi 9 (1): 62–63.

391. Nakazima, S. and K. Furukawa.
1933 **Bionomics and external structures of *Liparis dispar,* an insect noxious to *Livistona chinensis*** [in Japanese] Miyazaki Koto Norin Gakko Gakujutsu Hokoku (Bull. Miyazaki Coll. Agric. For.) 5: 1–12.

392. Nechleba, A.
1927. **The loss of vitality and destruction of broods of forest insect pests** [in German]. Anz. Scharedlinskd. 3(10): 115–117.

393. New Jersey Dep. Agric., Div. Plant Ind., Bur. Plant Lab.
1963. **Annual Report. 1962–1963.** 2p.
In 1962–63, New Jersey conducted a mass release of gypsy moth parasites, including three parasites from Spain which had not yet been established in the United States. These were *Tricholyga segregata,* a tachinid larval parasite; *Brachymeria intermedia,* a hymenopterous pupal parasite; and *Apanteles vitripennis,* a hymenopterous larval parasite. The state was in the process of releasing every known gypsy moth parasite it could locate.
**Eggs: 4; Larvae: 3,4; Pupae: 3,4**

394. New Jersey Dep. Agric., Div. Plant Ind., Bur. Plant Lab.
1965. **Annual Report. 1964–1965.** 1 p.
The state of New Jersey is still carrying on its mass release of gypsy moth parasites and predators to control population levels. Collections of egg masses were made from 21 sites. *Ooencyrtus kuwanae* was found to be established at five sites as a result of earlier parasite release programs.
**Eggs: 4; Larvae: 3,4; Pupae: 3**

395. New Jersey Dep. Agric., Div. Plant Ind., Bur. Plant Lab.
1966. **Annual Report. 1965–1966.** 1 p.
New Jersey continued its mass release of gypsy moth parasites. Recovery studies were also conducted to determine the establishment of parasites. *Brachymeria intermedia* was recovered for the first time since its release in New Jersey two years earlier.
**Eggs: 4; Larvae: 4; Pupae: 3,4**

396. New Jersey Dep. Agric., Div. Plant Ind., Bur. Plant Lab.
1967. **Annual Report. 1966–1967.** 1 p.
"During this past year, the [New Jersey Bureau of Plant Industry] Laboratory has initiated a parasite management program. The objective of this program is to release those numbers of various species of parasites into the gypsy moth population as required annually to prevent peaking of the host population." The following parasites were reared: *Ooencyrtus kuwanae, Sturmia scutellata, Compsilura concinnata, Apanteles melanoscelus,* and *Brachymeria intermedia.* These are "expected to be amenable to management under the proper conditions."
**Eggs: 4; Larvae: 4; Pupae:4**

397. New Jersey Dep. Agric., Div. Plant Ind., Bur. Plant Lab.
1969. **Annual Report. 1968–1969.** 2 p.
"For the past 5 years, the Plant Laboratory has increased its efforts in the rearing of gypsy moth parasites, as part of an integrated approach leading to the suppression of this forest pest." Besides the established gypsy moth parasites, the following exotic larval parasites were reared: *Apanteles porthetriae, Exorista rossica,* and *Exorista segregata."* A total of 15,795,844 parasites were released during the year. It is planned to release 25,000,000 parasites next year." A table of numbers of parasites released in each county is given, along with a table indicating the extent of establishment of the egg parasite *Ooencyrts kuwanae* in gypsy moth populations. "Surveys conducted during June revealed that six infested areas of the state have decreased in gypsy moth population or are about to do so. The factors responsible for these population declines are virus disease and parasitism."
**Eggs: 4; Larvae: 4; Pupae: 3,4**

398. New Jersey Dep. Agric., Div. Plant Ind., Bur. Plant Lab.

1970. **Annual Report. 1969–1970.** 8 p.

During 1969–1970, New Jersey kept its parasite release program in operation. The following exotic larval parasites were reared: *Apanteles porthetriae, Exorista rossica, Exorista segregata,* and *Rogas* sp. A total of 19,184, 758 parasites was released. Tables are given indicating the number of parasites released per county, a winter egg mass survey table indicating egg masses per plot and percent parasitism is included.

**Eggs: 4; Larvae: 4**

399. New Jersey Dep. Agric., Div. Plant Ind., Bur. Plant Lab.

1971. **Annual Report. 1970–1971.** 6 p.

At the present time, seven species of parasites and one predaceous beetle are well established in New Jersey. The established parasites are as follows: Egg parasite—*Ooencyrtus kuwanae.* Larval parasites—*Compsilura concinnata, Sturmia scutellata, Parasetigena agilis, Apanteles melanoscellus, Hyposoter dispar.* Pupal parasite—*Brachymeria intermedia.* Predaceous beetle—*Calosoma sycophanta.*

Of those parasites now established, three are maintained in the laboratory: *O. kuwanae, A. melanoscelus,* and *B. intermedia.* All others are field-collected. In addition, three native ichnuemonids (*Itoplectis conquisitor, Coccygomimus pedalis, Theronia atalantae*) and three native predaceous beetles (*Calosoma fridigum, C. scrutator, C. wilcoxi*) and one Pentatomid have been found attacking gypsy moth larvae and pupae. For the past three years (starting in 1969) there has been a steady collapse or decline of the gypsy moth populations in approximately one third of the defoliated areas. Most of this acreage has been defoliated for two years in succession. No large plots that have been defoliated in three years have been noted, but there are areas where the population has collapsed after one defoliation. Associated with population collapse is 60 to 90 percent parasitism by *O. kuwanae* and a high incidence of the wilt disease. In some areas the gypsy moth population remained stable; the major parasite in those areas was *P. agilis.* Four new parasites are being reared: three tachinids (*E. larvarum,* imported from Yugoslavia; *E. rossica,* imported from India; and *E. segregata,* imported from Spain), and the brachonid *Apanteles* sp., imported from Yugoslavia. Parasites released during the year are indicated in table form.

**All stands: 15; Eggs: 4; Generation: 1,7; Larvae: 4; Pupae: 3,4**

400. New Jersey Dep. Agric., Div. Plant Ind., Bur. Plant Lab.

1972. **Annual Report. 1971–1972.** 25 p.

The Plant Laboratory continued its mass rearing program of gypsy moth parasites and recently acquired 10 new parasites from India and southern France, which are being reared in the laboratory. The collapse of the gypsy moth population continued; 40 percent of the acreage defoliated declined in population. In some cases, in the year following decline, parasites damped off resurgence of the gypsy moth. This damp-off extended to perimeter areas expected to be defoliated. Parasites in the damping-off process are *Apanteles melanoscelus, Sturmia scutellata,* and *Parasetigena agilis.* There are also stable areas averaging 20 to 200 egg masses per acre. The parasites that damp off the gypsy moth population each year are *A. melanoscelus, Compsilura concinnata, S. scutellata, P. agilis,* and *Ooencyrtes kuwanae.* There appears to be a level of gypsy moth population necessary to maintain parasites for equilibrium or stability; no data are given. Although there are no parasites which alone can suppress the gypsy moth population, they contribute importantly to the dissemination of the virus disease. Parasites that are associated with different stages of the gypsy moth outbreak are listed. Ten woodland plots and 17 suburban plots were set up to establish relationships between man and gypsy moth outbreaks. The data are being processed by the Northeast Forest Experiment Station at Hamden, Conn.

**All stands: 15; Generation: 4**

401. New Jersey Dep. Agric., Div. Plant Ind., Bur. Plant Lab.

1973. **Annual Report. 1972–1973.** 44 p.

The New Jersey Plant Laboratory has continued its mass rearing and release of native and imported parasites of the gypsy moth. Seven species of parasites and one predaceous beetle have become established in the state. Trends of parasitism appear to be related to different levels of the gypsy moth population. Parasites are host-density-dependent in stable populations and appear to be factors in maintaining stability following collapse of the gypsy moth population. *Brachymeria intermedia*

appears to be effective only in heavily defoliated areas where a great deal of sunlight penetrates the forest canopy. Data show *Ooencyrtus kuwanae* is host-density-dependent as related to egg mass size. The fewer the number of gypsy moth eggs per mass, the greater the percent rage of parasitism by *O. kuwanae*.
**All stands; 15; Generation: 4**

402. New Jersey Dep. Agric., Div. Plant Ind., Bur. Plant Lab.
1974. **Annual Report. 1973–1974.** 40 p.
Since 1963 there has been a program for rearing parasites of the gypsy moth and for evaluating their effectiveness in the field. Data are given on this work.
**Generation: 4**

403. New York State Dep. Farms and Markets, Bull. 148.
1922. **The gipsy moth, an imminent menace to the forest and shade trees of the State of New York: present status of the gipsy moth situation and discussions at a conference held in Albany, Nov. 16, 1922.**
The article includes a discussion of life history, means of spread, food plants, parasites, predators, and control measures.
**Generation: 1,3,4; All stands: 15**

404. Nichols, J. O.
1961. **The gypsy moth in Pennsylvania—its history and eradication.** Pa. Dep. Agric., Bull. 4404. 82 p. Harrisburg.
Most outbreaks of gypsy moth occur at irregular intervals (in about four out of seven or eight years) in older infested areas of New England. An undetected build-up over several years on Mt. Yeager, near White Haven in Luzerne County, Pa., exploded in 1957. Every tree within 30 acres was defoliated, with partial defoliation of an additional 100 acres. Five hundred trees in the area were dead the following year, 95 percent directly or indirectly as a result of the gypsy moth; 99 percent of these were oak and 87 percent chestnut oak. The result was a decrease in percentage of oak from 90 percent to 75 percent.
**Oak stands: 20,25,27**

405. Nichols, J. O.
1968. **Oak mortality in Pennsylvania—a ten-year study.** J. For. 66: 681–694.
Three types of tree injury are considered in this study: defoliation, frost damage, and drought. These types of damage rarely cause mortality in the stand, and drought appears to be the most innocuous of the three. However, a decrease in radial growth is noted in these types of damage. Mortality of trees is due mainly to *Agrilus bilineatus* (Web.). Severe defoliation reduces the crown structure of trees to epicormic shoots on the bole and large branches. If defoliation is reduced and the trees do not succumb to *Agrilus,* they may recover. However, a long time is required for the epicormic shoots to be replaced by a normal crown structure.
**Oak stands: 15,16,18,21,24,25**

406. Nielsen, J. C.
1918. **Tachinid studies** [in Danish]. Vidensk. Medd. Dan. Naturhist. Foren. 69: 247–262.

407. Nishigaya, J.
1918. **On the caterpillars of *Lymantria mathura* that appeared in abundance on the apple in 1918** [in Japanese]. Insect World 22: 13–20.

408. Nishiguchi, C.
1961. **Larvae of the gypsy moth and tannin** [in Japanese]. Nippon Rin Gakkai-Shi 43(3): 226–228.

409. Nolte, H.
1938. ***Calosoma sycophanta* as an enemy of the nun moth** [in German]. Anz. Schaedlingskd. 14(11): 129–132.

410. Nolte. H.
1940. **Can the ground beetle (*Calosoma sycophanta* L.) stop a pest plague?** [in German]. Forstwiss. Centralbl. 62(6): 135–138. (English transl. by U.S. Dep. Agric. For. Serv. Telecom GM-75-7040).
The life history of *Calosoma sycophanta* L. is given, with emphasis on the interaction of numbers of prey and predator. Under natural conditions neither *Calosoma* nor other enemies is able to force the collapse of an insect outbreak. In America, where they have been artificially introduced, the beetles have adapted and multiplied because sufficient food was available from the beginning.
**Larvae: 3; Pupae: 3**

411. Nonell y Comas, J.
1913. **Cork tree pests in the province of Gerona** [in Spanish]. Rev. Inst. Agric. Catalan S. Isidro, Barcelona 62(23): 355–358.

412. Nunberg, M.
1925. **Massive occurrence of the gypsy moth (*Lymantria dispar* L.) near Boc hnia in 1924** [in Polish, German summary]. Pol. Pismo Entomol. 4(2): 118–133.

413. Oldiges, H.
1960. **Forest-floor fertilization and crown fauna** [in German, English summary]. Z. Angew. Entomol. 47(1): 57–60.
Tests in southern Germany in 1956 to 1959 on the effect of fertilizers applied to poor pine forest soils showed an increased mortality of *Dendrolimus pini* (L.) and *Panolis flammea* (Schiff.) when nitrogen was applied in the form of salt or ammonia gas. There was no increase in mortality of *Lymantria dispar* (L.) in beech or oak forests given similar treatment earlier in the same year. Evidently it was still too early for the treatments to have had an effect, since deeply rooted deciduous trees take longer to absorb the required amount of mineral fertilizer than pines
**Oak stands: 15, 19, 23; Larvae: 13**

414. O'Kane, W. C.
1922. **Division of insect suppression, plan and progress of work 1921–1922.** New Hampshire Dep. Agric., Div. Insect Suppression Circ. 15. 24 p.
*Schedius kuvanae* was unsuccessful as an imported parasite in New Hampshire owing to cold winters. However, *Anastatus bifasciatus* and *Apanteles melanoscelus* have become widely spread since importation.
**Instars I–III: 4; Generation: 4**

415. Operman, F.
1927. **Some notes on the gypsy moth (*Lymantria dispar* L.)** [in Serbo-Croatian, German summary]. Zagreb Sveuc. Zavod Sum. Pokuse. Glas Sum. Poluse 2:95–99.

416. Orlovskaya, E. V.
1961. **Research with polyhedrosis virus for control of the gypsy moth** [in Russian]. Byull. Vses. Nauchno-izsled. Inst. Zashch. Rast. 3–4: 54–57.

417. Orlovskaya, E. V.
1962. **Prospects for the use of viruses against insect pests [in Russian].** Zashch. Rast. Vred. Bolezn. 10: 20–23.

418. Orlovskaya, E. V.
1962. **Use of an experimental strain of nuclear polyhedrosis virus for creating epizootics in populations of the gypsy moth (*Porthetria dispar)*** [in Russian]. Vopr. Ekol. Kievsk. Univ. 8: 87–88.

419. Orlovskaya, Y. V.
1968. **Geographical distribution and manifestation of viral diseses in dendrophilous insect pests in the USSR.** Entomol. Rev. (English transl. Entomol. Obozr.) 47(4): 455–463.
A survey of viruses affecting insect pests in the USSR found 37 species affected by nuclear polyhedrosis viruses, 4 species of Lepidoptera and 1 of Coleoptera affected by cytoplasmic viruses, and 2 species of Lepidoptera affected by granulosis viruses. Nuclear polyhedrosis viruses sometimes cause total lysis or severe tissue damage, as is the case in epizootics. In nonepizootics, only small sections of tissue of the dead larvae are infected. During viral epizootics other pathogens are often encountered as well, or more than one type of virus may occur. The gypsy moth is affected by *Borrelinavirus reprimens* Holms., which was found in conjunction with microsporidiosis in all but one of the sites observed. External symptoms of virus usually appear a few hours before death: The larvae appear sluggish, softer, and relatively immobile, but without a color change in the integument. The internal contents of a newly dead gypsy moth are usually coffee-colored. In one of the observed sites, the gypsy moth hardly occurred for 7 years following an acute epizootic. Different species of insects are affected by the virus at different life stages. Viruses affecting one species of insect will not necessarily affect another, even if they exist in very close proximity.
**Larvae: 7,8**

420. Paillot, A.
1916. **The coccobacillus of the cockchafer: Its pathogenic action on some caterpillars of the macrolepidoptera** [in French]. C. R. Hebd. Seances Mem. Soc. Biol. Ses. Fil. 79(20): 1102–1103.

421. Paillot, A.
1917. **New parasitic microbes of larvae of *Lymantria dispar*** [in French]. C. R. Hebd. Seances Acad. Sci. 164(13): 525–527.

422. Paillot, A.
1917. **New microbe parasites of the cockchafer: their pathogenic action on the larvae of *Vanessa urticae, Lymantria dispar* and on silkworms** [in French]. C. R. Hebd. Seance Mem. Soc. Biol. Ses. Fil. 80(2): 56–58.

423. Paillot, A.
1919. **Contribution to the study of microbial parasites of insects: study of *Bacillus hoplosternus* (Paillot)** [in French]. Ann. Inst. Pasteur, Paris 33(6): 403–419.

424. Pantyukhov, G. A.
1962. **The effect of positive temperatures on different geographic populations of the European gold tail (*Euproctis chrysorrhea* L.) and the gypsy moth (*Lymantria dispar* L. — Lepidoptera: Orgyidae).** Entomol. Rev. [English trans. Entomol. Obozr.] 41: 169–175.
In the active phases of the life cycle of the gypsy moth, the rate and period of development in relation to temperature, lower thresholds, totals of effective temperatures, and optimum temperatures are almost identical irrespective of geographic location. Physiological indices are also identical.
**Generation: 12,13**

425. Pantyukhov, G. A.
1964. **The effect of low temperatures on different populations of the brown-tail moth, *Euproctis chrysorrhoea* L., and the gypsy moth, *Lymantria dispar* (L.) (Lepidoptera: Orgyidae).** Entomol. Rev. (English transl. Entomol. Obozr.) 43: 47–55.
Susceptibility of gypsy moth eggs to cold during diapause is dependent on the climate of the area where the eggs are laid. In northern regions, the eggs contain more fats and carbohydrates, depressing the freezing point of the liquids in the egg. Differences in gypsy moth populations with respect to susceptibility of eggs to cold are completely physiological. Before and after diapause the individuals are identical. These physiological differences might, however, be the beginning of intraspecific differentiation.
**Eggs: 12,13**

426. Parker, D. L.
1933. **The interrelations of two hymenopterous egg parasites of the gipsy moth, with notes on the larval instars of each.** J. Agric. Res. 46: 23–34.
Tests were designed to show interrelations in the population dynamics of two gypsy moth egg parasites. It was concluded that it is advantageous to have both parasites in the same locality, as there is little serious competition between them. Because *Anastatus disparis* adults are probably more numerous at the time of deposition of host eggs, the potential for competion is greater when *Anastatus* attacks first and *Ooencyrtus kuvanae* then attempts to reproduce in the same gypsy moth egg. *Anastatus* does not suffer from these attacks. When *Anastatus* attacks a gypsy moth egg containing *Ooencyrtus* in the egg stage, the *Anastatus* develops. When *Ooencyrtus* is in the larval or pupal stage and the host egg is attacked, neither parasite develops. *O. kuvanae* hibernates in forest debris as an adult female, emerges in the first warm days of April, and oviposits later in the month. This first generation develops in 6 weeks, and the adults emerge in late May. A second generation emerges in early July and a third develops in 3 weeks on newly deposited gypsy moth eggs, emerging in August. There is time for four with a partal fifth generation in New England, but there are large losses over winter and many parasites in the early spring generations are oviposited into infertile and dead host eggs. Thus *O. kuvanae* is not considered as well suited to the gypsy moth life cycle as is the univoltine *A. disparis,* which overwinters in the host egg as a full-fed larva and emerges at the time of maximum gypsy moth oviposition in July. It develops from egg to mature larva in 12 to 15 days. It was found in the course of the investigations that both of these parasites have five larval instars, not three as was previously thought.
**Eggs: 4**

427. Parrott, P. J.
1913. **New destructive insects in New York.** J. Econ. Entomol. 6: 61–68.
The gypsy moth was first discovered in New York by W. J. Schoene of the Geneva Experiment Station on June 22, 1912. The infestation was believed to be no more than 3 years old and to have started from one egg mass, probably brought in on nursery stock. The infestation was confined to

a few old apple trees in a residential section. The New York Department of Agriculture spared no effort to exterminate the insect, which people were surprised to find in the western part of the state and not in the region adjoining Massachusetts.
**Non-oak stands: 15**

428. Patočka, J. and M. Čapek.
1971. **Population changes of certain oak defoliators (Lepidoptera) in Slovakia.** Acta Inst. For. Zvolen. 1971: 461–485.

In Slovakia, outbreaks originate from foci located in areas of high-quality food. Young larvae are especially sensitive to food quality. As an outbreak progresses, however, the population expands to less favored habitats. The initiation of an outbreak depends on the absence of a cold weather spell in mid-May, which usually occurs in Slovakia. *Calosoma sycophanta* population density depends on gypsy moth population density. During the innocuous phase of the gypsy moth population, *C. sycophanta* is very rare. The following parasites are always present, but appear to have little effect on the gypsy moth population density: *Apanteles solitarius, Compsilura concinnata, Parasetigena silvestris,* and *Sturmia scutellata.* Collapse of severe outbreaks is usually dependent on the virus *Borrelina reprimens* and the microsporidia *Nosema lymantriae.*
**Generation: 1,7,8,12; Larvae: 3,4**

429. Patočka, J.
1973. **Influence of food and location on the mortality of some injurious Lepidoptera living on oak** [in German, English summary]. Vest. Cesk. Spol. Zool. 37(4): 282–292.

"By field experiments, it was proved that the kind and quality of food and the character of the community have a significant influence on the mortality of several oak pests of the order Lepidoptera."
**Generation: 12**

430. Patterson, T. L.
1911. **Technical results from the gipsy moth parasite laboratory: III. Investigations into the habits of certain Sarcophagidae.** U.S. Dep. Agric., Tech. Ser. 19: 25–32.

Since species of Sarcophagidae were known to be primary parasites of grasshoppers and numerous species of Sarcophagidae had been reared in association with the gypsy moth, there was a question of whether they were purely scavengers on dead gypsy moth larvae or whether they were parasitic, causing the death of the larvae. It was found that female Sarcophagidae would not oviposit in freshly killed material, whereas they would in older, decomposing larvae, thus refuting the parasite theory. When larvae had been dead for 2 days, the female would crawl all over, make buzzing noises with her wings, puncture decaying skin several sections behind the head with her proboscis, and move her ovipositor directly over the puncture. She would larviposit, and the maggot would work its way into the body. Gypsy moth larvae, therefore, must be at a stage at which there is already an incision in the skin, or one could easily be made with the proboscis. No sarcophagids were reared from 2666 living gypsy moth larvae collected in the field, indicating conclusively that sarcophagids in New England were not parasitic on gypsy moth larvae. Also, no first-stage maggots developed when placed artificially within living pupae. Sarcophagids were more commonly associated with the gypsy moth in Europe and Japan. It is possible there are several parasitic species there.
**Generation: 13; Larvae: 4; Pupae: 4**

431. Pawlowicz, J.
1936. **Observations on some hymenopterans and dipterans parasitizing *Porthetria dispar* L., *Malacosoma neustria* L. and *Stilpnotia salicis* L. (Lep.)** [in German]. Zool. Pol. 1(2): 99–118.

432. Petre, Z.
1965. **Contributions to the study of an aspect of the polyhedrosis virus of *Lymantria dispar* L.** [in Romanian]. Stud. Cercet. Bidh. Ser. Bot. 17(3): 339–347.

433. Piatnicky, G. K.
1935. **Factors causing and controlling a mass increase of gypsy moth in Crimea** [in Russian, English summary]. Vopr. Ekol. Biolsenol. 2: 100–119.

Close observation of neglected forests, especially of hornbeam and curly oak, can give early indications of the gypsy moth outbreaks in the Crimea. Outbreaks begin rapidly (within 1 to 2 years), spreading over mountainous and submountainous regions, but not above an altitude of 600 to 800 m because of weather conditions. Distribution of gypsy moths over the outbreak region is predictable owing to their xerophylous nature: They increase in young, thin, uniform plantations and on

southern mountain slopes. The climax of the propagation usually occurs in the second or third year of the outbreak, followed the next year by a territorial shifting and a general reduction in area. This can be predicted: niduses of the following year are formed in, and practically coincide with, the borders of plantations where less than 50 percent of the foliage was injured the preceding year and which had no fewer than one larva per tree. Not more than one-half this number will form dense niduses. Control of the gypsy moth in the Crimea should be sought by maintaining mature, dense woods, planting nonpreferred species, locating and destroying small niduses, and using aviochemical methods.
**Generation: 2,12**

434. Picard, F.
1921. **The gypsy moth (*Lymantria dispar*)** [in French]. Prog. Agric. Vitic. 76(33): 160–165.

435. Picard, F., and G. R. Blanc.
1913. **Coccobacilli infections in insects** [in French]. C. R. Hebd. Seances Acad. Sci. 157(1): 79–81.

436. Picardi, A. C.
1973. **Gypsy moth population simulation: system postulation, validation, analysis.** Proc. 1973 Summer Computer Simulation Conf., Montreal. 73 CH0815-1 SMC: 1069–1074.
"This paper presents the results of a simulation and policy analysis of gypsy moth population dynamics. The case study affords an opportunity for some methodological observations on model postulation, validation, and selection of a simulation language for the particular system presented. Policy simulations showed [that] gypsy moth pheromones [are] effective in eliminating the pest in low-density areas and that nonpersistent sprays could be useful in reducing high-density populations to the levels at which pheromones would be effective."
**Eggs: 4; Generation: 2; Instars I–III: 1,6; Instars IV–VI: 6; Larvae: 9,10; Pupae: 3,4; Sex ratio: 6**

437. Pictet, A.
1919. **Experimental research on the adaptation of *Lymantria dispar* to conifers and to other varieties of trees** [in French]. Mitt. Schweiz. Entomol. Ges. 13(1): 20–54.

438. Podgwaite, J. D., and R. W. Campbell.
1970. **Disease in natural gypsy moth populations** Pages 279–284 *in* 4th Int. Colloq. Insect Pathol., College Park, Md.
"Diseased larvae of the gypsy moth *Porthetria dispar* (L.) from both sparse and dense populations were examined and categorizes on the basis of mortality factors. A significantly higher incidence of parasitoids, few bacterial pathogens, and the virtual nonexistence of polyhedral viruses were noted in the relatively stable sparse populations. Nuclear polyhedorsis probably represented the primary mortality factor in the dense populations, while pathogenic bacteria played a lesser role. Many insects examined from both population types revealed no infectious agent or overt cause of disease, a fact that may implicate noninfectious disease as a regulator in natural populations."
**Larvae: 4,5,6,7,8**

439. Podgwaite, J. D., and R. W. Campbell.
1972. **The disease complex of the gypsy moth.** II. Aerobic bacterial pathogens. J. Invert. Pathol. 20: 303–308.
"Eighty-six pathogenic aerobic bacterial isolates from diseased gypsy moth larvae collected in both sparse and dense populations were characterized and identified as members of the families Baccillaceae, Enterobacteriaceae, Lactobacillaceae, Pseudomonadaceae, and Achromobacteraceae. The commonest pathogens were *Streptococcus faecalis, Bacillus cereus, Bacillus thuringiensis,* Group C *Enterobacter* types, and *Pseudomonas* spp. However, *S. faecalis* and *B. cereus* were found operating only in the dense populations. The wide range of potentially pathogenic bacteria encountered may indicate that under conditions of high host density these bacteria may contribute significantly to the population dynamics of the gypsy moth."
**Generation: 2; Larvae: 5**

440. Prell, H.
1925. **On *Apanteles solitarisu* Ratz. as a parasite of nun moth larvae** [in German]. Anz. Schaedlingskd. 1(9): 103–105.

441. Proper, A. B.
1934. **Hyperparasitism in the case of some introduced lepidopterous tree defoliators.** J. Agric. Res. 48: 359–376.

Hyperparasites of the gypsy moth, the brown-tail moth, the oriental moth, and the satin moth play a major role in reducing the numbers of primary parasites. An average of almost one third of the cocoons and puparia are destroyed by them. In almost every case, each primary parasite has one species of secondary parasite that is far more abundant than any other. Parasitism of the cocoons of *Apanteles melanoscelus* was found to be 32.5 percent in the first generation and 84.4 percent in the second, with *Eurytoma appendigaster* (Swederus) the most abundant parasite. Depending on the primary host of *Compsilura concinnata* Meigen, hyperparasite relationships differ; the gypsy moth is hyperparasitized chiefly by *Dibrachys boucheanus. Brachymeria compsilurae* was found responsible for most of the 11 percent of paraistism of *Sturmia scutellate,* which is practically a specific parasite of the gypsy moth in New England. It lays eggs on the foliage where they are eaten by fourth-instar larvae.

**Instars** I–III: **4; Instars** IV–VI: **4**

442. Prüffer, J.
1923/24. **Observations and experiments on the sex manifestations of *Porthetria dispar* L.** [in Polish]. Rozpr. Wydz. Mat. Przyr. Pol. Akad. Umiejet. Ser. III. 23/24(A/B): 97–106.

443. Prüffer, J.
1937. **Further investigation on the male lure of *Lymantria dispar* L. (Lep.)** [in German]. Zool. Pol. 2(1): 43–66.

444. Pschorn-Walcher, H.
1964. **On the parasites of some injurious Lepidoptera from northern Japan.** Tech. Bull. Commonw. Inst. Biol. Control 4: 24–37.

A severe outbreak of gypsy moth was recorded in 1961 in the Tachikawa Forest District. Defoliation occurred exclusively in young larch plantations. One thousand each of larvae and pupae were collected for a parasite survey. *Apanteles liparidis* Bé. was the most numerous parasite. *Pimpla disparis* Vier. was the only other Hymenoptera encountered. *Brachymeria fiskei* Crawf. was also found, but it is believed usually to hyperparasitize tachinids. The tachinids *Exorista japonica* T. T., which is the Oriental counterpart of the European *E. larvarum,* and *Eucarcelia separata* Rond. were found. Both are very polyphagous. *E. separata* is also an important parasite in Yugoslavia. Larvae of a sarcophagid fly were quite abundant, but it was not ascertained whether they were primary parasites or whether they attacked cadavers of virus- killed larvae.

**Generation: 4; Non-oak stands: 15**

445. Rao, V. P.
1966. **Survey for natural enemies of gypsy moth.** PL 480: Project No. A7-FS-8, Grant No. FG-In-112. Commonw. Inst. Biol. Control, Bangalore, India. 50 p.

*Lymantria obfuscata* Walker occurs in the states of Assam, Himachal Pradesh, and Jammu and Kashmir in northern India. *L. dispar* does not occur in India. Illustrations are given comparing the external morphology of the adults and chaetotaxy of the larvae of these two species. The life history and morphology of *L. obfuscata* are described in detail, and much information is given on its natural enemies. *Anastatus* spp. parasitized up to 25 percent of the eggs of *L. obfuscata* in some places. *Apanteles* sp. (possibly new ) and *A.* sp. nr. *conspersae* parasitized 25 to 30 percent of larvae in certain locales. In Sprinagar *A. liparidis* was reared from early-instar larvae as a solitary parasite, whereas at Kotgarh it was gregarious and parasitized later-instar larvae. *Rogas* sp. controlled the population of instars II and III at Kulu. *Exorista rossica* Mesnil, *Drino discreta* Wwp., *Compsilura concinnata* Meigen, and *Ctenophorocera caerulea* Jaenn. Sub. sp. *maculisquama* were predominant among the Tachinidae which parasitized 15 to 25 percent of later-instar larvae annually. *Brachymeria euploeae* (Westwood) and *B. intermedia* were the most important pupal parasites, followed by *Pimpla* sp. and *Theronia* sp. The egg predators *Anthrenus* sp. probably *museorum* and *Orphinus* spp. were unimportant as control agents, but *Calosoma himalayanum, Campalita auropunctatus,* and *Craspedonotus himalayanum* were active against full-grown larvae. *Streptococcus,* nuclear polyhedrosis virus, *Bacillus* sp., *Alcaligenes* sp., *Brevibacter,* and *Aeromonas* sp., were isolated from diseased larvae. Diseases caused 10 to 25 percent larval mortality, with an increase in virus disease the last two years of the study.

**Eggs: 3,4; Instars** I–III: **4; Instars** IV–VI: **3,4; Larvae: 5,6,7; Pupae: 4**

446. Rao, V. P.

1972. **Evaluation of hymenopterous parasites of the gypsy moth and study of the behavior of promising species.** PL 480: Project No. A7-FS-F1, Grant No. FG-In-304. Commonw. Inst. Biol. Control, Bangalore, India. 44 p.

Serological tests proved that *Lymantria dispar, L. obfuscata,* and *L. ampla* are different species. Parasites of *L. obfuscata,* the Indian gypsy moth, were evaluated for potential use in controlling *L. dispar* in the United States. *Exorista rossica* Mesnil and a possibly new species of *Apanteles* were considered the most valuable for this purpose.

**Generation: 4,13**

447. Reardon, R. C.

1970. **A new species of *Rogas* parasitic on the gypsy moth, *Porthetria* dispar (Hymenoptera: Braconidae).** Proc. Entomol. Soc. Wash. 72(4): 473-475.

*Rogas indiscretus* n.sp. is described (U. S. National Museum type no. 70842). It is an important parasite attacking early-instar larvae of *Lymantria obfuscata* Walker in the northeastern part of the Punjab, India. It was first reared on gypsy moth larvae in 1967 and released the following year. Initial recovery attempts from the release points in Connecticut and Massachusetts were unsuccessful in 1969.

**Instars** I-III: **4, 13**

448. Reardon, R. C., M. W. Statler, and W. H. McLane.

1973. **Rearing techniques and biology of five gypsy moth parasites.** Environ. Entomol. 2: 124-127.

Biological data on five parasites of the gypsy moth are given: *Exorista rossica* Mesnil, tachinid from Kashmir, India; *Rogas indiscretus* Reardon, braconid also from India; *E. segregata* (Rondani) and *Apanteles porthetriae* Muesebeck, from Spain; and *A. melanoscelus* (Ratzeburg).The Indian species were reared from *Lymantria obfuscata.*

*E. rossica* parasitizes 15 to 25 percent of host larvae in Kashmir, completing three generations per year. Adults emerge at the beginning of May; the second generation begins in early June and the third in early July. One to three eggs per healthy host are laid in the thoracic region. Eggs are laid over a 25-day period, with a total of 250. A few mature host larvae or prepupae are parasitized. In the laboratory about one half as many eggs are laid; fourth and fifth instars are preferred. Parasite puparia are produced in 20 percent of host larvae if one egg is laid, 40 percent if two, 50 percent if three, 67 per1cent if four, and 71 percent if five eggs are laid on the host. In the field, *E. rossica* needs an alternate host for overwintering.

*E. segregata* is an important parasite in southern Europe, and *E. lavarum* is common in central Europe (also established in New England). All are successful parasites in their native habitats, which are quite different. Their behavior is similar to *E. rossica. R. indiscretus* attacks early instars of *L. obfuscata* in northeast India, parasitizing about 25 percent. Adults are in the field from May to June. The parasites form cocoons within mummified host larvae cadavers; they are abundant and obvious in mid-May. A high proportion of cocoons diapause over winter and emerge in spring. *R.indiscretus* attacks larvae somewhat later than *Apanteles* and earlier than *E. lavarum.* In the laboratory, one female *A. melanoscelus* parasitized an average of 15 larvae per day for a total of 75 cocoons produced. Information is given on laboratory biology.

*A. porthetriae* is a common solitary parasite throughout Europe. It is very numerous in large, open-grown oaks of south and central Europe and attacks early instars. It has been reared from *L. obfuscata* in India. There were many early attempts to establish it in the United States. It has a very similar biology to *A. melanoscelus,* except that it does not diapause as a pupa and therefore needs an alternate host.

**Instars** I-III:**4,12; Instars** IV-VI: **4,12**

449. Reardon, R. C.

1973. **A survey for tachinid parasitoids of the gypsy moth on Cape Cod, Massachusetts.** Environ. Entomol. 2: 964-965.

Gypsy moth larvae were collected on five 1-acre plots and maintained in a laboratory. Parasite activity for the area was estimated from the parasites that emerged from the larvae. In 1970 and 1971, *Parasetigena agilis* (Robineau-Desvoidy) averaged 72 percent and 67 percent of the total parasitism, respectively. *Compsilura concinnata* (Meigen) and *Blepharipa scutellata* (Robineau-Desvoidy) comprised of 28 percent and 33 percent for 1970 and 1971, respectively. *Exorista rossica* Mesnil and *E. segregata* (Rondani) are two exotic species released in 1968, 1969, and 1970. *E.*

*larvarum* (L.) is also an exotic species previously released. These three species of tachinids were not recovered in the experiment.
**Instars IV–VI: 4**

450. Reiff, W.
1911. **The "wild disease," or "flacherie" of the gypsy moth.** Wright and Potter Printing Co., Boston. 60 p.

This is a report of early experiments on the gypsy moth wilt disease as well as a review of other larval diseases, including diarrhea, bead disease, muscardine, and pebrine. The influence of flacherie (wilt disease) on gypsy moth larvae depends on the manner and time of its appearance. There does not seem to be a difference in effect between a natural outbreak and artificially developed flacherie. Female larvae succumb to the disease more readily than males, perhaps because of their longer maturation period. Wilt causes females to lay very small egg clusters containing incompletely developed embryos. A high percentage of dead eggs are found in flacherie-infected areas. The author suggests that the disease may be passed transovarially, which means that the embryos are killed as a result of the organism itself and not as a result of the weak constitution of the female moth. The still-living embryos of the cluster then become carriers, and succumb to the disease at some point in the larval stage. The author recommends artificially introducing flacherie as a means of controlling the gypsy moth.
**Larvae: 6,7,8; Sex ratio: 6**

451. Rexrode, C. O.
1971. **Insect damage to oaks.** Pages 129–134 *in* Oak Symp. Proc. U.S. Dep. Agric. For. Serv., Northeast. For. Exp. Stn., Upper Darby, Pa.

Defoliation is a serious threat to oaks at this time. Continuous moderate defoliation of 1 year of heavy defoliation does not kill trees. Two consecutive years of 60 to 100 percent defoliation will cause mortality. Mortality is often not the direct result of defoliation but the result of borers and fungi which attack after the tree is weakened by defoliation.
**Oak Stands: 15,25**

452. Richerson, J. V., and E. A. Cameron.
1974. **Differences in pheromone release and sexual behavior between laboratory-reared and wild gypsy moth adults.** Environ. Entomol. 3: 475–481.

"Wild female *Porthetria dispar* adults emitted attractant at any time of day but made a maximal release between 1000–1530 h. Pheromone emission is greatest during the first 3 days of a virgin female's adult life and after the third day decreases until death. Wild females emit a burst of pheromone, as much as 841 ng/30 min, once in their life, usually on the second or third day. After the burst, the amount of lure emitted decreases rapidly. Unlike wild females, laboratory-reared (lab) females show no diel periodicity in pheromone emission, and release very small amounts of pheromone (4.9 ng/30 min). Laboratory and field bioassays indicated that approximately 30 percent of both sexes of lab moths either did not respond to pheromone or released no detectable amount of lure, compared with 9 percent sexual inactivity in wild moths."
**Adults: 1,13**

453. Richerson, J. V., E. A. Brown, and E. A. Cameron.
1976. **Pre-mating sexual activity of gypsy moth males in small plot field tests (*Lymantria (Porthetria) dispar* (L): Lymantriidae).** Can. Entomol. 108: 439–448.

"Pre-mating behavior of male gypsy moths was investigated in 0.2 ha circular plots containing from 0 to 72 virgin females/plot in untreated areas and in areas treated with an aerial application of 20 g/ha microencapsulated disparlure. Male moths in both treated and untreated plots oriented initially to trees, not directly to females. Mating was disrupted in treated plots but males continued search behavior. No anemotactic behavior was evident in either treated plots or untreated plots with females. In untreated plots, male moths were not caught on sticky panels (panels suspended at 2, 4, and 6 m) higher than pheromone-baited traps set at 2 m. In treated plots, equal number of males were caught at all panel heights and in baited traps at 2 m. Previous mating and pheromone exposure histories of males did not affect the response of

these males to traps baited with 4–5 mg of disparlure in untreated plots. In a test of the relative attractiveness of a cotton wick and a new laminated bait dispenser in Johnson traps, traps baited with the laminated dispenser had a greater male moth catch/male contact to trap than the traps baited with the cotton wick. Not all males contacting the Johnson trap were caught. A mode of action for disparlure as a disruptive agent in the long-range sexual communication system of gypsy moth is proposed."

**Adults: 1**

454. Richerson, J. V., E. A. Cameron, and E. A. Brown.

1976. **Sexual activity of the gypsy moth.** Am. Midl. Nat. 95(2): 299–312.

"Female moths that had begun to deposit unfertilized eggs (spewing females) did attract males and were mated. However, only females that had spewed fewer than 10 eggs before mating were likely to deposit fertile eggs after mating. Males in a natural infestation did not discriminate between mated, virgin, spewing and nonspewing females. Both sexes of the gypsy moth were capable fo mating several times in 24 hours. About one third of the males in a dense population were mating with previously mated females. In the microencapsulated, disparlure-treated plots, only 1- to 4-day-old females were mated. In untreated plots, 1- to 8-day-old females were mated. Furthermore, fewer females tethered in the litter in the treated plots were mated than those females tethered in the litter in control plots. The disparlure treatment reduced the incidence of mating. In treated plots, more females tethered on the tree at 2 m were mated than females tethered in the litter. Videotaped activity of males in a dense population revealed that male orient to vertical silhouettes initially, and not to specific pheromone sources."

**Adults: 1**

455. Romanyk, N.

1958. **The treatment and the parasitism of *Lymantria dispar* in the oaks of Salamanca** [in Spanish]. Bol. Serv. Plagas For. 1(1): 27–32.

This discussion concerns the gypsy moth outbreak of 1955–57 in Salamanca and the combined effect of chemicals and parasites as control mechanisms. The outbreak began in scattered foci observed for the first time in 1952. It spread rapidly and in 1956 involved more than 100,000 hectares between pure *Quercus ilex* forests and mixed oak woodlands. Chemical dusts were used, but owing to economic constraints the treated areas were limited and total annihilation was not achieved. In the spring of 1957, three zones could be delineated: (1) zone without treatment, with outbreak conditions; (2) zone treated in 1956 with light reinfection; and (3) zone treated in 1955, reinfected but without reaching outbreak characteristics. In 1955 few parasites were observed; in 1956 *Apanteles vitripennis, Compsilura concinnata, Tricolyga grandis,* and a smaller number of *Brachymeria intermedia* were observed; in 1957—with up to 800 and more egg clusters per tree—there was still relatively little parasitism of eggs but more than 90 percent mortality of larvae and pupae. Larval mortality was attributed to *A. vitripennis* since their cocoons were observed on all trees. Pupal mortality was due to *B. intermedia* (32.5 percent), *Monodontomerus aereus* (52.5 percent), and tachinids (6 percent). The parasitism had the same characteristics in treated and untreated zones, demonstrating that treatments with dust are not so dangerous for parasite fauna as would be expected. The chemical treatments normally end before *L. dispar* larvae reach 2 cm and, with the exception of *Apanteles,* all the parasites enumerated above attack their host at a later stage. As a consequence of the parasites and the treatments, the *L. dispar* outbreak entered a regressive phase, disappearing completely in many places and remaining strong only in a few foci.

**Oak Stands: 15; Eggs: 4; Larvae 4,12; Pupae: 4**

456. Romanyk, N.

1960. **A new focus of *Lymantria dispar* L. in the oak forest of Toledo y Avila** [in Spanish]. Bol. Serv. Plagas For. 3: 41–46.

457. Romanyk, N. and A. Ruperez.

1960 **Principal parasites observed in the defoliators of Spain with particular attention to *Lymantria dispar* L.** [in Spanish, French summary]. Entomophaga 5(3): 229–236.

458. Romanyk, N.

1965. **The study of parasites, predators, and diseases of the gypsy moth (*Lymantria dispar*) and the possibility of their application in biological control.** Final Technical Report, Project No. E-25-FS-10, Grant No. FG-Sp-106-60. Servicio de Plagas Forestales, Madrid, Spain. 65 p.

A study was conducted from 1960 to 1965 on the parasitology and pathology of the gypsy moth, with special attention to parasites in Spain, that do not exist in the United States. The gypsy moth is a principal defoliator in Spain, especially of *Quercus ilex* (evergreen oak) and *Q. suber* (cork oak), both of which occupy large areas. *Q. ilex* is treated as a fruit tree (acorns are used for cattle feed), and its stands do not resemble forests. The plantation floor is pasture or cultivated. Intensive defoliation lasts 2 to 4 years, with a loss in productivity but with no mortality. The egg parasite *Anastatus disparis* is native to Spain, has one generation per year, and parasitizes only freshly laid eggs before the larvae are formed. In this study, there was 9.2 percent parasitism by *A. disparis*. *Ooencyrtus kuwanae* How. has several generations per year, prefers mature eggs with formed embryos, parasitizes only the upper layer of the egg cluster, and prefers eggs not covered with hairs. It will reproduce and live in a sterile gypsy moth egg. Its optimum fecundity is 200 eggs, and it will parasitize 15 to 20 percent of larvae. *Carabus gongoleti* Reiche was considered an important predator in the 1922–1923 outbreak but now is insignificant. *Calosoma sycophanta* is valuable. Its development is delayed with respect to the gypsy moth gradation, and thus it does not prevent outbreaks. At least 1.5 percent of pupae in all foci were attacked by dipteran scavengers during the first 4 years of the study, and more than 4 percent were attacked in 1964, especially by *Agria affinis* Fall. as well as by *Sarcophaga uliginosa* Kram., *S. tuberosa* Pand., and *Sarcophaga,* sp. The most important larval parasite, *Tricholyga segregata* Rond., was also found in a 1913–1936 study and identified as *T. grandis,* It has many hosts, overwinters in puparia in soil, and emerges when the gypsy moth is in its last instar. Generally, it lays one egg per larva and has perhaps two generations per year. Its fecundity varies from 270 to 620, probably as a result of feeding conditions in the larval state. *T. grandis* parasitizes 13 to 35 percent of gypsy moth larvae and needs a Mediterranean climate.

*Exorista larvarum* (Tachinidae), resembles *T. segregata* and emerges from pupae at the same time. It constitutes usually 5 percent of the total and causes 1.5 to 3 percent of the parasitism. *Hemipenthis morio* L. (Bombylliidae) is an ecto-hyperparasite on the overwintering pupae of both tachinids, killing about 90 percent during two years of the study. Hyperparasitism on Diptera pupae is generally high. *Brachymeria intermedia* Nees. is polyphagous and widespread in Europe and North Africa. It has at least two generations per year on different hosts. It overwinters as an adult, its size depending on the size of the host. It will oviposit only on pupae 2 to 4 days old, which are not completely hardened. Parasitized pupae then dry up. *B. intermedia* shows no preference for one sex over the other and has no regular hyperparasites. Its range is from 13.9 to 65.2 percent parasitism, with a mean of 31.8 percent. Lows for *B. intermedia* and *T. segregata* were from the same area in 1962 when there were great storms.

*Apanteles vitripennis* Hal. is widely distributed in Spain. It oviposits on the dorsal thorax in any of the early instars, preferring instar II. In the field, larvae develop in 12 to 20 days, bore out the ventral or lateral side, and make cocoons attached between the thoracic and abdominal legs of the gypsy moth. The gypsy moth larvae then move to shaded locations under leaves or on bark and die in a few days. There are two generations per year in Spain with one egg per gypsy moth larva. Even when only a small number of gypsy moth larvae is exposed to them, *Apanteles,* for unknown reasons, will not parasitize them all. Parasitism varies greatly within a focus, averaging out to a low 10 percent. *Apanteles* pupae are hyperparasitized in low numbers by *Hemiteles longicauda* Ths. and *Eurytoma verticillata* Fob. *A. vitripennis* is the most important species of the genus in Spain. During this study, there was no instance of significant parasitism by other *Apanteles* or by *Meteorus versicolor* Wesrn., perhaps because some *Apanteles* need an alternate larval host for overwintering and the other *Q. ilex* defoliators also overwinter as eggs. *Pimpla instigator* F. destroyed more than 20 percent of pupae in an isolated case

on Menorca Island; otherwise they are rare. Unfavorable weather conditions are felt more by the parasite than by the host. In the study area, parasites were generally active, but defoliation was heavy, especially in the last three years.

In general, parasitology is not a sufficient natural control. Observations over five years show that microbial enemies have been important only in isolated cases. *Nosema lymantria* Weiser, *N. muscularis* Weiser, and *Plistophora schubergi* Zwolfer are protozoans pathogenic to gypsy moth. They appear spontaneously in instars IV and V, causing a reaction in the gypsy moth, that increased logarithmically with respect to dose and size. In the laboratory, spores were ingested with food and germinated. The new form migrated to body interior, affixed to specific tissue, and sporulated. The spore stage can resist great temperature and humidity change but is very sensitive to ultaviolet light. The nonspore stage is very delicate and susceptible to adverse weather conditions. No clear relationship was found between ingested dose of virus and disease production.

There was no epizootic in the field during the study. Fungi are not of utilizable pathogenicity. Bacteria behave logarithmically vis-à-vis dose ingested and animal size. Toxins affect nervous centers and cause paralysis. Spores germinate, migrate across the intestinal wall, reproduce, sporulate, and release septicemin which causes death. Toxic pathogenicity varies with strain. *Bacillus entomocidus* var. *subtoxicus, B. thuringiensis* Sotto, *B. thur.* (Vankova) *IHA, B. thur.* Galenae (Russian) *HA-3,* and *B. cereus* are effective against the gypsy moth. Their activity is proportional to pH, increasing with acidity.

**Oak Stands: 15,25; Eggs: 4; Instars I–III: 4; Instars IV–VI: 4; Larvae 5,7,8; Pupae: 3,4**

459. Romanyk, N.
1966. **Natural enemies of *Lymantria dispar* L. in Spain** [in Spanish, English summary]. Bol. Serv. Plagas For. 9(18): 157–163.

From 1959 to 1965 studies were done on the foci of the *Lymantria dispar* L. existing in Spain, in connection with the natural enemies of this defoliator . . . Among the first-instar larvae parasites, the following stand out: *Anastatus disparis* Muschka and *Ooencyrtus kuwanae* How. The average percentage of parasitized eggs was 9.2 percent for the first and 15 to 20 percent for the second. Among the last-instar larvae parasites, *Apanteles vitripennis* Hal. stands out with 7 to 14 percent of parasitized caterpillars. A mortality rate of 16 to 30 percent was observed among the last-instar larvae as result of *Tricholyga segregata* Rond. and *Exorista larvarum* L. parasitism. Finally, the *L. dispar* L. pupae suffered a parasitism between 20 percent and 62.5 percent, depending on the years, by *Brachymeria intermedia* Nees. Among the predators, *Calosoma sycophanta* was especially noted for its abundance."

Studies were carried out on the possibility of rearing and reproducing some parasites in the laboratory. "Protozoa, fungi, bacteria, and viruses have been observed among the microorganisms. They appeared sporadically and irregularly. A protozoan of the *Nosema* genus was found in abundance in the provinces of Toledo and Salamanca; as it did not have any of the characteristics of the known *Nosemas* of *L. dispar* L., it was described as *Nosema muscularis toletanica* (Ruperez, 1965). Fungi of [the] *Aspergillus* and *Beauveria* . . . [generally] appeared in relative abundance for only one year on pupae.

The bacterial complications have been frequent, but no satisfactory results have been obtained in the experiments carried out on the preparations made with native species. Better results were obtained with strains of the *Bacillus cereus-thuringienis* group, which have not been isolated in Spain. In the experiments made with virus preparations, the results obtained have always been very contradictory. Two virus diseases of intranuclear activity produced by bacilliform virus have been detected in existing foci of *L. dispar* L., and another virus disease of cytoplasmic activity caused by cocciforme virus was found on intestinal wall cells."

**Eggs: 4; Generation: 5,7,8; Instars IV–VI: 4; Pupae: 4**

460. Rotschild, E.V.
1958. **Extermination by rodents of the gypsy moth in the area of mass reproduction** [in Russian]. Byull. Mosk. O-Va. Ispyt. Prir. Otd. Biol. 63(4): 129–130.

Analysis of stomach contents revealed that three small mammal species (*Apodemus flavicollis, A. sylvaticus,* and *Dyromys nitedula*) were eating gypsy larvae and pupae in a forest area east of the Ural Mountains. Stomachs contained legs, head parts, and parts of integument and internal parts,

but very rarely hair. Often stomachs were filled exclusively with remains of larvae or pupae.
**Larvae: 10; Pupae: 10**

461. Rubtzov, I. A.
1938. **The theoretical basis of the distribution of harmful insects and of predictions as to their mass multiplication: the effect of constant and variable temperatures on the development of the eggs of the gipsy moth (*Porthetria dispar* L.)** [in Russian, English summary]. Zashch. Rast. (Leningrad) 17: 25–38.

The end of diapause and the simultaneous drop in the threshold of development do not occur suddenly but proceed gradually during several months. "The eggs of *Lymantria dispar* L. show the following modification in the threshold of development. The development of the eggs does not commence immediately after they are laid, the threshold of development being about 10°C in January, and then gradually falling during February to May to 5 to 6°C. The calculated threshold of development is about 3 to 4°C. At constant temperatures, the duration and speed of development of the eggs of *Lymantria dispar* L. follow Sanderson-Blunk's formula only in the most general manner. The regular deviations observed here principally consist in slowing-down of development when the temperature departs from the optimum toward the zones of depression. The rate of development, however, again shows a relative acceleration near the limits of life, especially at the lower temperature threshold of development. These data indicate that Janisch's exponential curve is more accurate and gives a more complete representation of the actual curve of development at various temperatures."
**Eggs: 12**

462. Rudnev, D.F.
1962. **On the reasons for the reproduction of forest pests on a large scale** [in Russian]. Vopr. Ekol. Vyssh. Shk. Moscow 7: 157–160.

463. Ruperez, A.
1964. **Microsporidia parasites of *Lymantria dispar* L.** [in Spanish, English summary]. Bol. Serv. Plagas For. 7: 129–131.

"A microsporidium of *Nosema* species, found on *Lymantria dispar* L., is compared with three other species which have been described to date. It is concluded that there is a possibility of having discovered a new species which is provisionally described with the name *Nosema muscularis toletanica* n.s. sp. . . . Its pathogenic value on *Lymantria dispar* L. has been confirmed, but new experiments should be done in the near future on pathogenic selectivity for certain tissues and for some other insect species."
**Larvae: 8**

464. Ruperez, A.
1964. **Optimum time for the proliferation of the polyhedrosis of the larvae of *Lymantria dispar* (Lepidoptera: Lymantriidae)** [in French, English summary]. Pages 516–520 *in* (Collog. Int. Pathol. Insect Lotte Microbiol., Paris, 1962.

In the last six years, the pathology of *Lymantria dispar* larvae has been studied in the field , using treatments with virus suspensions of *Borrelinavirus reprimens.* The results obtained with this microbiological control are discussed. Laboratory and field observations indicate that virus preparations might be used successfully in a program of microbiological control.
**Larvae: 7**

465. Russo, G.
1959. **The principal parasites of forest defoliating Lepidoptera in Italy** [in Italian, English summary]. Boll. Lab. Entomol. Agrar. "Filippo Silvestri" 17: 172–188.

"The most important Lepidoptera injurious to forest trees in Italy and their parasites are indicated. The importance of bioecological researches on entomophagous insects which attack pests injurious to forests in Italy is stressed, particularly with regard to the possibility of introducing and establishing foreign parasites which seem to be very promising in other countries. The ecological advantages of mixed forests with regard to the activity of the oligophagous and polyphagous species of parasites are stressed. The dangers connected with the use of organic synthetic insecticides in the control of forest pests are discussed, while the importance of biological control against such insect pests is stressed.
**Generation: 4**

466. Russo, G.
1960. **The principal insect parasites of the lepidopterous forest defoliators in Italy and**

**their economic importance** [in Italian, French summary]. Ann. Acad. Ital. Sci. For. 9:139–151.

467. Ryvkin, B. V.
1951. **Some questions relating to the biology of the tachinid *Sturmia inconspicua* Meig. (Diptera, Larvivoridae) and its economic importance** [in Russian]. Dokl. Akad. Nauk. SSSR 76(5): 755–758.

468. Ryvkin, B. V.
1957. **Peculiarities of the gypsy moth outbreaks and their causes** [in Russian, English summary]. Zool. Zh. 36(9): 1355–1358.

The gypsy moth very often appears in abundance, and its outbreaks are very prolonged. Sometimes the gypsy moth migrates from its original location. "Insufficient ecological plasticity of the specific parasite of its eggs, *Anastatus disparis* (Rusch.), and of some other of its parasites have to be considered as well. According to the data of 74 areas of different districts of the European part of the USSR, the eggs of the gypsy moth oviposited in 1951 were parasitized to 1.9 percent and the eggs oviposited in 1953 (17 areas) were parasitized to 1.3 percent. Only in few areas did parasitism of the eggs reach 10 to 25 percent . . . [Other parasites]—Tachina flies, *Compsilura concinnata* Meig., *Phorocera silvestris* R.D., *Sturmia scutellata* R.D.—decrease the population density of the pest only to an insignificant degree. Preservation of the natural resources of *A. disparis* is carried out by means of collecting ovipositions of the gypsy moth in autumn and by keeping them in warm buildings in winter."

**Eggs: 4; Generation: 2; Larvae: 4**

469. Salatić, S.
1963. **Results of investigations of some factors in the effectiveness of gypsy moth egg parasites** [in Serbo-Croatian, English summary]. Zast. Bilja. 14(76): 693–699.

Studies of the effectiveness of Hymenoptera egg parasites showed that the development of *Anastatus disparis* Ruschka is not completely synchronized with that of its host. Many of the parasites emerge early in spring when the host is not in a stage that allows regeneration of the parasite. Imagos emerge 3 weeks after oviposition into the eggs of the host. Diapause does not occur at all. The males emerge first, followed a few days later by the females. The life of the male is very short (4 to 5 days), while females live up to 49 days. The percentage of parasitism depends upon the thickness of the egg cluster. In upper layers, the eggs are more heavily parasitized than in lower ones.

**Eggs: 4**

470. Sampo, A.
1968. **On the resinophilous allotrophy(change of food) of some Lepidoptera of forestal importance** [in Italian, English summary]. Ann. Fac. Sci. Agrar. Univ. Studi Torino 4: 317–344.

*Lymantria dispar* was observed feeding on *Picea pungens* in Valentine Park, Turin. The damage stunted the growth of the spruce plantation.

**Non-oak stands: 15**

471. Sandquist, R. E., J. V. Richerson, and E. A. Cameron.
1973. **Flight of North American female gypsy moths.** Environ. Entomol. 2: 957–958.

Limited evidence of flight of female gypsy moths is presented. This is neither a normal activity nor a significant factor in adult dispersal.

**Adults: 1**

472. Schaffner, J. V., Jr.
1927. **Dispersion of *Compsilura concinnata* Meig. beyond the limits of the gipsy moth and the brown-tail moth infestation.** J. Econ. Entomol. 20: 725–732.

By 1922, *Compsilura concinnata* had spread 100 miles westward beyond the known limits of gypsy moth and brown-tail moth infestations and was thriving on native pest insects. Its spread westward from New England was more rapid than its southward spread. It was discovered in the area south of the Adirondacks and in the Catskills.

**Instars IV–VI: 4**

473. Schaffner, J. V., Jr.
1934. **Introduced parasites of the brown-tail and gipsy moths reared from native hosts.** Ann. Entomol. Soc. Am. 27: 585–592.

Twelve of the larval parasites introduced into the United States in the campaign against the gypsy moth, the brown-tail moth, the satin moth, and the oriental moth are known to be firmly established. Five of these, *Apanteles lacteicolor* Vier., *A. melanoscelus* Ratz., *Compsilura concinnata* Meig., *Meteorus versicolor* Wesm., and *Sturmia*

*scutellata* R.D., have been reared from field collections of native larvae. *A. melanoscelus* and *C. concinnata* can exist in this country independent of the hosts for which they were introduced. The latter, which requires alternate and hibernating hosts, has found a variety of suitable host species that have enabled it to disperse far beyond the limits of the infestation of the pests for which it was introduced.
**Larvae: 4**

474. Schedl, K. E.
1936. ***Porthetria dispar* in Euroasia, Africa and New England** [in German]. Z. Angew. Entomol. Monogr. 12. 242 p.
Review of the world literature on the gypsy moth through the mid-1930's.
**Review; bibliography**

475. Schieferdecker, H.
1969. **The reproduction of *Oencyrtus kuwanae* (Howard, 1910) under laboratory conditions** [in German, English and Russian summaries]. Beitr. Entomol. 19(7/8) : 803–815.
"*Ooencyrtus kuwanae* (Howard, 1910) can be grown in the laboratory on eggs of *Lymantria dispar* even if the latter have been sterilized. Their suitability as hosts decreases with increasing heat. They can be stored at +2°C for 35 days. The parasites can develop even in eggs from which the larvae are about to emerge if there are at least 6 days at 20°C between oviposition and the emerging of the larvae. The parasites are attracted most by normal batches of eggs and least by sterilized and washed single eggs from which the hair has been removed . . . Freshly emerged females reach the peak of their oviposition at 20°C on the fourth and fifth days of their lives. Ninety-five percent of all eggs are laid within 11 days. The optimum temperature for the full utilization of the fertility is 21°C (with an average of 54 offspring per female). The optimum density of parasites for mass breeding is five female parasites on 100 *Lymantria* eggs."
**Eggs: 4**

476. Schmidt, L.
1959. **Effect of temperature and humidity in the time of the moulting period on the development of gypsy moth's caterpillars** [in Serbo-Croatian, English summary] Zast. Bilja 56: 53–60.
High relative humidity and low temperatures during molting induce physiological weaknesses which cause longer developmental periods and death of larvae. These climatic conditions cause a disorientation of the larvae so that often they do not feed immediately after molting. Polyhedrosis virus manifests itself in acute form under such conditions.
**Larvae: 7,12,13**

477. Schneider-Orelli, O.
1913. **On *Lymantria dispar* and *Euproctis chrysorrhoea*** [in German]. Schweiz. Z. Obst-Weinbau 22(2–3): 18–22, 38–41.

478. Sellers, W. F.
1953. **A critique on the time factor in biological control.** Bull. Entomol. Res. 44: 273–289.
The author discusses points raised in papers by Clausen (1951) and Thompson (1951). Clausen's main point was that on the basis of field observations, an introduced entomophagous parasite or predator that is to be effective will achieve full commercial control within three host generations, or within 3 years at the most, in the vicinity of colonization points. Full commercial control is the degree of control rendering other measures unnecessary. Thompson states the problem mathematically: $n = pst$, where $n$ = host population, $p$ = parasite population, $s$ = effective reproduction rate/generation, and $t$ = number of generations. Both agree there is no evidence of progressive adaptation which can transform an ineffective parasite into an effective one, but Thompson suggests more time may be necessary than Clausen allows. L. O. Howard and others suggest the parasite may need time to adapt to the new environment, but the author suggests this may mean that time is needed for adequate establishment in the form of an equilibrium of distribution, after which the parasite can respond effectively. Four

factors are common to most cited cases of successful biological control: an initially high host population which allows the natural enemy to approach its potential reproductive rate; only one species of parasite or predator; a slow rate of dispersal with several host generations per annum; and the effective reproduction rate of the parasite exceeding that of the host. Here the host supply tends to a maximum, and parasite increase occurs in a restricted area where it is immediately effective. No cases of effective control of a univoltine host by an introduced univoltine parasite were cited by Clausen. An "equilibrium of distribution" must be established at the colonization site before the pest is exposed to the full effectiveness of the reproductive increase of the introduced insect. Equilibrium is obtained when there is no reduction in numbers of the parasite due to outward dispersal into uncolonized areas. They gypsy moth is presented as an example of the complexities involved in control. Unlike theoretically uniform populations, there are periodic local outbreaks of the gypsy moth for 3-year periods. That they are brought under control in 3 years may suggest that the controlling agencies are effective parasites. If the potential host population is below the capacity of the environment, parasitism is of control value. However, if the parasite merely reduces the population to a supportable level, the value is questionable, because without control the host would have eliminated itself by exhausting the food supply.
**Generation: 2,4**

479. Semevsky, F. N.
1971. **Optimization of caterpillar behavior in the gypsy moth (*Porthetria dispar* L.) in relation to their distribution in crown** [transl. from Russian UDK 595787: 591.51] Zh. Obshch. Biol. 32(3): 1–8.

This paper is based on the premise that larvae will optimize their behavior for maximum survival. An increase in mortality rate is observed in high levels of population density as a result of an increase in migrational intensity. First-instar larvae migrate upward to terminal leaves. If only one larva is present on the leaf, it will commence feeding. If more than one is present, the larvae swing the head and thorax until they are lifted by the wind, thus migrating to a new area. This behavioral mechanism reduces the possibility of starvation even in an outbreak situation.
**Instars I–III: 1**

480. Semevsky, F. N.
1972. **Prognosis in forest protection** [in Russian]. Lesn. Prom-St.' 1972. (English transl. by U.S. Dep. Agric. For. Serv. Telecom. GM-75-7098.)

"The bases for the theory of linear prediction are presented in this work . . . . [Its usefulness in predicting] the effects of . . . . . gypsy moth populations [of varying size is] examined. A critical analysis of existing practice is made. Reference materials on fodder norms, survival rates, decreased growth, and resistance of various species of trees to defoliation are given. Contemporary mathematical methods, which are of interest because of the application of mathematics to ecology, are presented."
**All stands: 15; Generation: 2**

481. Semevsky, F. N.
1973. **Studies of the dynamics of the numbers of the gypsy moth *Porthetria dispar* L. (Lepidoptera: Lymantriidae) at low population density levels.** Entomol. Rev. (English transl. Entomol. Obozr.) 52(1): 25–29.

"Studies were made of the population dynamics of the gypsy moth in the period between outbreaks. The method used consisted . . . [of] introducing test insects into the biocoenoses and observing their mortality . . . [The] results show that in periods between outbreaks the estimate of mortality due to predators is 0.957, that due to abiotic factors and diseases 0.56, and that due to parasites 0.55. It is concluded that in periods of depression the main role in the population dynamics of the gypsy moth is played by mortality due to predators and that mortality due to parasites does not increase significantly in the outbreak period. Migration and mortality from diseases in crowded hungry populations probably act as the regulator of population numbers."
**Generation: 4, 6**

482. Serafimovski, A.
1954. **A new gradation of the gypsy moth** [in Macedonian, French summary]. Sumar. Pregl. 2: 60–71.

483. Shapiro, V. A.
1956. **Principal parasites of *Porthetria dispar* L. and the prospects of using them** [in Russian]. Zool. Zh. 35(2): 251–265.

484. Shtcherbakov, T. S.

1914. **Observations on the gipsy moth (Lymantria dispar L.)** [in Russian.] Works of natural history museum of the Tauric Government Semstvo, 1914, Vol. III. Tauric Government Semstvo Press, Simpheropol (English transl.).

Detailed morphological descriptions of the egg and early instars are given. The phenomenon of larval flight is discussed. In experiments with first-instar larvae and food plants, all larvae offered arbor vitae or pine died without injuring the tree. Those given medlar or willow did not die, nor did they injure the tree. Wild cherry was slightly damaged, but after 15 days the larvae had not molted. Typical feeding holes were made on quince, and larvae molted on the 8th or 9th days. Larvae did best on apricot, apple, and pear, preferring flower buds to the leaves. In general, more of the leaf surface is damaged and destroyed than consumed. Workers in different parts of the world report different food plant preferences. Experiments showed that instar I larvae can live 10 to 11 days without food, but the dorsum turns black and there is a weight and size loss.

**Instars I–III: 1,13; Non-oak stands: 15**

485. Sinitsky, N. N., and I. M. Kireeva.

1968. **Dynamics of fat metabolism in pupae of *Bombyx mori* L., *Antheraea pernyi* G. M., and *Porthetria dispar* L. under different ecological conditions** [in Russian, English summary]. Vestn. Zool. 2(4): 51–55.

"The pupae of the investigated species differ in the quantitative fat content, while the type of changing fat metabolism completely coincides. During the initial and terminal periods of pupa development, a considerable amount of fat is spent, while in the intermediate period the fat expenditure remains low. The highest fat expenditure is observed at the second part of metamorphosis. Photothermal conditions affect the dynamics of fat metabolism in pupae. At low temperatures with a prolongation of illumination period, the metamorphosis duration is reduced and intensity of fat metabolism dynamics is somewhat increased. Under conditions of elevated temperature the minimal expenditure of general fat amount is observed under conditions of 12- to 17-hour illumination."

**Pupae: 12,13**

486. Sinitsky, N. N., A. V. Bogach, and I. M. Kireeva.

1971. **The role of temperature and light in the development and reproduction of certain species of Lepidoptera** [in Russian]. Page 440, vol. 1., Proc. 13th Int. Congr. Entomol., 1968. Nauk. Leningrad.

487. Sisojević, P.

1957. **Natural enemies of the gypsy moth** [in Serbo-Croatian]. Biljni Lek. 1957: 15–16.

488. Sisojević, P.

1959. **Investigations of the prepupae and pupae of the gypsy moth in Yugoslavia in 1958 (annual report, 1958)** [in Serbo-Croatian, English summary]. Zast. Bilja 52/53: 174.

The aim of this study "is to record the insect parasites of the prepupae and pupae of the gypsy moth [and] to evaluate the size of the prepupae and pupae, sex ratio of adults, and the degree of parasitism as indicators of the population density and as a tool in forecasting."

**Prepupae: 4,13; Pupae: 4,13**

489. Sisojević, P.

1960. **Ecological studies of tachinid parasites of the gypsy moth (annual report, 1959)** [in Serbo-Croatian, English summary]. Zast. bilja 56: 113–115.

Three years after the population density of the gypsy moth reached its peak, the numbers of the moth have continued to decline and have sunk to extremely low levels (39 larvae/120 ha). "At the same time, only two species of the tachinid flies were found parasitizing the caterpillars of the gypsy moth: *Phorocera agilis* R.-D. and *Compsilura concinnata* Meig. The other eight species of tachinids (*Carcelia excisa* var. *separata* Rond., *Zenillia libatrix* Panzer, *Drino inconspicua* Meig., *Blepharipoda schineri* Mesnil, *Blepharipoda scutellata* R.-D., *Blondelia nigripes* Fall., *Exorista larvarum* L., *Exorista fasciata* var. *moreti* R.-D.) which were parasitizing the gypsy moth in previous years have not been found this year. Out of 28 caterpillars found on May 20, 15 (53.5 percent) had the eggs of *P. agilis;* 40 percent of them were superparasitized. That observation shows that this tachinid fly possesses a very good host-searching ability and that it may therefore exercise a significant role in reducing the numbers

of the host population even at its very low level. The mortality of the caterpillars caused by *P. agilis* was 35.9 percent; by *C. concinnara,* 7.7 percent. The alternate hosts were recorded for the species *P. agilis, C. concinnata,* and *Blondelia nigripes,* namely *Eriogaster* sp. and a geometrid for *P. agilis,* three noctuids and one arctiid for *C. concinnata,* and two noctuids for *B. nigripes.*"
**Larvae: 4**

490. Sisojević, P.
1960. **Investigations of the prepupae and pupae of the gypsy moth in Yugoslavia (annual report, 1959)** [in Serbo-Croatian, English summary]. Zast. Bilja 56: 117–118.

"In this year the population density of the gypsy moth was so low in all 86 observed localities that the prepupae and pupae could not be found, the only exception being one locality) Stip, Macedonia). It was possible to find only 160 prepupae and pupae. The results of analysis of that material are: The size of the prepupae and pupae varied from medium to small, but medium-sized individuals predominated; the percentage of female adults was 42.9 percent; the total mortality (parasitism and mortality caused by other factors) amounted [to ] 47.5 percent. According to these data, it seems unlikely that the population density of the gypsy moth will fall to the minimum in the next year. The main mortality factor was the tachinid fly *Blepharipoda scutellata* R.-D."
**Prepupae: 4; Pupae: 4; Sex ratio: 2**

491. Sisojević, P.
1975. **Population dynamics of tachinid parasites of the gypsy moth (*Lymantria dispar* L.) during a gradation period** [in Serbo-Croatian, English summary]. Zast. Bilja 26(132): 97–170.

The population dynamics of 10 tachinid parasites of the gypsy moth were studied from 1954 to 1960 in a 100-hectare lowland stand of *Quercetum roboris* at Jakovački Ključ in Serbia. The population density and parasitism of the oligophagous tachinids showed the same trends as the gypsy moth, but with their maximum densities delayed 1 or 2 years. With the polyphagous parasites, the trend was quite different, with the highest percentage of parasitism in the progression phase. In latency, only *Compsilura concinnata,* the most polyphagous of the tachinids studies, parasitized the gypsy moth. A moderate host density provides the most favorable conditions for increase of the parasites.
**Oak stands: 15; Larvae: 4; Prepupae: 4; Pupae: 4**

492. Škorić, V.
1926. **Causes of dying away of our oak forests** [in Serbo-Croatian, English summary]. Zagreb Sveuc. Zavod Sum. Pokuse. Ann. Exp. For. 1: 234–246.

This is a study of the characteristics of oak dieback in Slavonia. Shortly after foliation, leaves are eaten by larvae of *Lymantria dispar, L. chrysorrhea,* and *Malacosoma neustria. L. dispar* is the problem in most forests. Upon refoliation, the new leaves are attacked by the powdery mildew of oak, *Microsphaera alphitoides* Griff et Maubl., which thrives in dry air, in light, and near its temperature optimum. These conditions are met at the time of midsummer refoliation, especially by trees at the forest edge and those of stool-shoots, which the author found to be attacked most strongly. Many young oaks die after the third defoliation in one season. The vitality of older trees is lowered, as evidenced by invasion of *Xyleb* or *us* (Platypus) and *Agrilus* (Buprestidae). The fungus *Agaricus mellea* Quel. then invades via the insect wounds. The initial insect defoliation does not cause oak decay but sets the stage for this complex of fungi and insects.
**Oak stands: 15,16,24,25**

493. Smiley, D.
1964. **The gypsy moth in Ulster County.** John Burroughs Nat. Hist. Soc. Nat. Sci. Ser. 4(1): 1–11.

This is a review of the history, life cycle, food habits, and history of control of the gypsy moth.
**Generation: 1,12**

494. Smiley, D.
1967. **Conversations on ecology** XIX. Garden J. 1967 (March/April): 66–68.

Up to 1954, local infestations west of the Hudson River in New York State were rare and controlled from the ground. In 1954 strong easterly winds picked up young larvae east of the Hudson and dispersed them through Ulster and Greene counties. Early in 1957, the U.S. Department of Agriculture began aerial spraying of DDT on 3 million acres in the Northeast to destroy the gypsy

moth. They claimed complete success in eradicating it. In 1964, however, there was extensive forest tree defoliation on the dry ridges of the Shawangunks, and in 1965 thousands of acres in Ulster County were defoliated. In 1966 the egg-mass count was very high, and large areas were treated with Sevin. A 7500-acre tract in Mohonk, New York, owned by the author, was not chemically treated and was two-thirds defoliated. But as the larvae began to pupate, many fell to the ground and died before pupating. Others pupated, but their pupal cases were small. Almost no females emerged, and few egg masses were found. The author believes this decimation of the population was a result of viral disease and parasites. He opposes "controlling" the gypsy moth because oaks on dry ridges have become the dominant species as a result of human intervention and are destined to decline anyway.

**Generation: 2; Instars I–III: 2; Larvae: 4,7; Oak stands: 15,19**

495. Smiley, D.

1971. **Gypsy moths and man: a story of mutual accommodation.** John Burroughs Nat. Hist. Soc. The Chirp 18(4): 1–8.

A balanced ecosystem will control the gypsy moth over time. Deep snow allows shrews to eat eggs from the lower trunk. Wet weather in late spring limits build-up. Low spring rains are favorable to the gypsy moth and detrimental to trees. If gypsy moth defoliation occurs during drought, it may be beneficial to the tree since moisture is conserved, as happens when a tree is pruned. Larger larvae will feed on needle-bearing trees when forced to move from stripped deciduous trees. They eat only the outer parts of needle bundles; therefore a tuft of needles remains which allows the tree to survive until new needles are put out the next year. It is rare for defoliation to occur often enough in succession to kill many trees. Trees in Mohonk are not defoliated as severely the second year. When an area infested with gypsy moths is not sprayed, a small population is maintained even during low points in the cycle. These in turn maintain a parasite population that is responsive to an increase in the gypsy moth population. "Any form of pesticide control is *worse* then useless."

**Eggs: 10; Generation: 2,4,12; Non-oak stands: 15**

496. Smiley, D.

1975. **Gypsy moths and man: a story of mutual accommodation.** John Burroughs Nat. Hist. Soc., Ecosystem Sketch 22 and The Mohonk Trust Publ. 5. 9p.

This outlines the ecology of the gypsy moth and describes its effects on the Mohonk Forest in New York, which has been kept spray-free. This area has shown a steady decrease in gypsy moth egg density from 3581 egg masses (E. M.)/15-acre plot in 1971 to 88 E. M./plot in 1975. The gypsy moth will present no more problems at Mohonk, the author believes, because of the changing species composition of the forest due to earlier heavy repeated defoliation. The forest at Mohonk is reaching a "Natural accommodation" with the gypsy moth, and the natural enemies of the gypsy moth are expected to hold the population in check. Therefore, there is no need for artificial control.

**Oak stands: 24; All stands: 15,18,28; Generation: 7,12; Larvae: 9; Pupae: 9,10**

497. Smilowitz, Z., and L. Rhoads.

1973. **An assessment of gypsy moth natural enemies in Pennsylvania.** Environ. Entomol. 2: 797–799.

"An investigation was conducted to determine qualitatively the entomophagous natural enemies of *Porthetria dispar* (L.) in Pennsylvania. Seven exotic species were recovered: the larval parasites *Blepharipa scutellata* (Robineau-Desvoidy) (Tachinidae), *Compsilura concinnata* (Meigen) (Tachinidae), *Phobocampe disparis* (Viereck) (Ichneumonidae), and *Apanteles melanoscelus* (Ratzeburg) (Braconidae); a pupal parasite, *Brachymeria intermedia* (Nees) (Chalcididae), and *Ooencyrtus kuwanai* (Howard) (Encyrtidae), an egg parasite. The predator *Calosoma sycophanta* L. (Carabidae) was observed feeding on gypsy moths in one county. Two native ichneumonid parasites were recovered in the State, *Theronia atalantae fulvescens* (Cresson) and *Itoplectis conquisitor* (Say). A *Calosoma* beetle and two species of Pentatomidae were observed feeding on the gypsy moth in the field."

**Eggs: 4; Larvae: 3,4; Pupae: 3,4**

498. Smith, H. E.

1917. **Notes on New England Tachinidae, with the description of one new genus and two new species.** Psyche J. Entomol. 2(2): 54–58.

The parasite *Compsilura concinnata,* imported from Europe, has been recovered from the gypsy moth. As many as five individuals have matured in one host. This tachinid apparently overwinters in the host pupa. In early April when the parasite is ready to pupate, it emerges from the pupa but remains inside the pupal case of the host.

**Pupae: 4**

499. Soule, A. M. G.

1913. **Parasite introduction ot Maine.** Q. Bull. Maine Dep. Agric. Augusta. 12(4): 10–18.

The parasites that have been reared in Maine or imported to control gypsy moth outbreaks are listed. General life histories are given for each parasite.

**Eggs: 4; Larvae: 4; Pupae: 3**

500. Spurr, S. H., E. W. Littlefield, and H. A. Bess.

1947. **Part II. Ecology of susceptible and resistant forest types and stands.** Pages 27–39 *in* H. A. Bess, S. H. Spurr, and E. W. Littlefield, eds. Forest site conditions and the gypsy moth. Harv. For. Bull. 22. Petersham, Mass.

This is a detailed analysis of the various elements hat comprise forest types susceptible or resistant o gypsy moth defoliation. Favored food plants requently occur in susceptible stands, but their resence alone does not indicate stand susceptibilty. The defoliation potential of a stand is better elated to land-use history, soil, physiography, nd plant indicator species that reflect the enironmental conditions. Nonfavored food plants ay be defoliated when the environmental condiions are particularly well suited for maintaining a igh larval population. Resistant stands are charcterized by loamy soils, a moderately dense own canopy, vigorous timber growth, and deep ter. Wild sarsaparilla, maple- leafed viburnum, rowwood, New York fern, wood fern, and hristmas fern are the characteristic shrub and rbaceous indicators. Overstory indicators are gar maple, white ash, black birch, basswood, llow poplar, beech, and hemlock. In an oak and, a high proportion of red oak indicates resistnce. Sandy plains and ridges tend to be susceptite to gypsy moth outbreaks. They are characterized by black, scarlet and white oaks, gray birch, and aspen in the overstory; pine, scrub and white oaks in the understory; and lowbush blueberry, sweet fern, huckleberry, bracken, sedges, bayberry, and bush honeysuckle as groundcover. Most susceptible stands are pioneer forest associations which would become resistant with time if left undisturbed. Moderately heavy gypsy moth defoliation of these pioneer species hastens forest succession, but frequent severe defoliation creates conditions favorable for future outbreaks by opening up the stand, drying out litter, and setting back succession. Whole forest regions are resistant to heavy defoliation because they contain little favored food, or are confined to better sites, or have unfavorable climates. It is safe to assume that future heavy defoliation will be in areas ecologically similar to those that proved susceptible in New England.

**All stands: 15,18,19,20,21**

501. Stadler, H.

1933. **A new ichneumonid from gypsy moth larvae (*Lymantria dispar* L.)** [in German]. Entomol. Anz., Wien 13(2–4): 27–30, 43–45, 58–60.

502. Staley, J. M.

1965. **Decline and mortality of red and scarlet oaks.** For. Sci. 11: 2–17.

"Declining and dying *Quercus rubra* L. and *Q cocinia* Muench. were found to be affected by leaf roller defoliation, root rot, *Agrilus* attack, late spring frost, drought, and unfavorable soils. Symptoms of decline were reproduced artificially by defoliation of sapling *Q. rubra.* Other factors, such as root rot, drought, and frost, are considered contributory but not primarily causal. It was concluded that the initial symptoms of decline reflect a diminished availability of carbohydrates for growth, and that final symptoms of subsequent mortality reflect extreme moisture stress. A similar decline of European oaks is pointed out."

**Oak stands: 16,17,18,23,25**

503. Stauder, H.

1913. **Contribution to the biology of the caterpillars of *Lymantria dispar* L. (Lep., Lym.) and *Phalacropteryx praecellens* (Lep. Psych.)** [in German]. Z. Wiss. Insektbiol. 9(5): 148–151.

504. Stefanov, D.
1960. **A biological adaptation of the gypsy moth (*Lymantria dispar* L.)** [in German]. Proc. 11th Int. Congr. Entomol., 1960, vol. II, sec. VIII: 262–265.

505. Stefanov, D., and M. Keremidchiev.
1961. **The possibility of using some predators and parasitic insects (entomophages) in the biological control of the gypsy moth (*Lymantria dispar* L.) in Bulgaria** [in Bulgarian, German summary]. Nauchni Tr. Vissh. Lesotekh. Inst. Sofia 9: 157–168.

506. Stephens, G. R., and D. E. Hill.
1971. **Drainage, drought, defoliation, and death in unmanaged Connecticut forests.** Conn. Agric. Exp. Stn. Bull. 718. 49 p.

Natural changes in four Connecticut forests were examined from 1959 to 1970, related to defoliation, drought, and soil drainage and compared with four other Connecticut woodlands previously studied. The four tracts all lie in Connecticut's upland region of metamorphic rock and glaciated soil, but otherwise differ from one another in soil, climate, and history. Drought did not significantly alter the mortality rate, but repeated defoliation increased mortality on all but poorly drained soils. Death of major species was 1.3 percent baseline, 1.5 percent in a dry site defoliated once, and 2.3 percent annually in moderate and well-drained sites defoliated twice. The mortality rate of oak, the prime target of defoliators, doubled with repeated defoliation.

**All stands: 15,27,28**

507. Stephens, G. R.
1971. **The relation of insect defoliation to mortality in Connecticut forests.** Conn. Agric. Exp. Stn. Bull. 723. 15 p.

From the standpoint of the effect on trees, the identity of the defoliating insect is important only insofar as it affects the time of defoliation and the amount of foliage removed. Defoliation early in the growing season is especially critical because new foliage does not become functional immediately and is produced at the expense of stored reserves. A single defoliation within a decade, as seen in this study, did not increase mortality beyond that in undefoliated stands. Mortality increased after two defoliations on medium-moist sites and three consecutive defoliations on dry sites. A single defoliation had little effect on mortality of trees in the canopy, but repeated defoliations did have an effect, especially on dry sites. White and chestnut oaks succumbed more readily than did red oaks. Oak mortality was greater than that of maples even in undefoliated sites. Repeated defoliation increased the loss of large oaks, but had little effect on maple, black birch, or yellow birch. One possible reason for the greater mortality among oaks is that they are attacked by defoliators more than other trees. However, there has been a decrease in the number of oaks in Connecticut forests since 1927, perhaps reflecting a gradual change in forest conditions since burning and clearcutting are no longer practiced.

**All stands: 15,19,23,27,28**

508. Summers, J. N.
1916. **Parasites of the gypsy and brown-tail moths in Maine.** Annu. Rep. Maine Comm. Agric., 1915. 14: 120–127.

This is a brief history of parasites introduced into Maine. *Anastatus bifasciatus* oviposits in gypsy moth eggs, the maggots devour the entire contents of gypsy moth eggs, then overwinter in the empty shell. They emerge just before new gypsy moth eggs are laid in late summer. *Apanteles lacteicolor* attack brown-tail and gypsy moths. They overwinter as maggots inside young brown-tail larvae. When these emerge from their webs in the spring, the *Apanteles* begin feeding. They emerge and spin cocoons at the end of May. The next generation attacks young gypsy moth larvae. When brown-tail larvae hatch in late summer, they are attacked by adults of this generation of *Apanteles*. *Meteorus versicolor* is very similar to *Apanteles*. Its cocoon hangs from trees by a fine thread. *Compsilura concinnata* deposits maggots inside larvae of both pests; these feed and emerge to form puparia. A number of broods develop in the summer. They also attack injurious native insects. *Calosoma sycophanta* is an important predator. According to the author, property owners "should not expect too much of the parasites."

**Eggs: 4; Instars I–III: 4**

509. Summers, J. N.
1922. **Effect of low temperature on the hatching of gypsy moth eggs.** U.S. Dep. Agric. Bull. 1080. 14 p.

An exposure of between −20° and −25°F is necessary to kill entire gypsy moth egg masses.

Temperatures around −15°F will kill some of the eggs in the mass. Survival during severe winters depends largely on protection from wind by aspect and snow cover during temperature plunges.
**Eggs: 12**

510. Švestka, M.
1970. **Gradations of gypsy moth in stands of black locust** [in Czechoslovakian]. Lesn. Pr. 49(11): 519–521.

511. Szalay-Marzsó, L.
1957. **Observations during the summer of 1954 and 1955 in the Nyíregyháza forest in connection with the outbreak of *Lymantria dispar* L.** [in Hungarian; Russian and English summaries]. Ann. Inst. Prot. Plants Hung. 7: 113–123.

In the summer of 1954, an outbreak of *Lymantria dispar* was observed in the Nyíregyháza forest. It fully developed in 1955 and defoliated about 250 "cadastral yokes" of the forest's *Quercus pedunculata* stock. Most of the starving larvae in the defoliated region died of a virus disease, and only about 10 percent of the larval population reached a pupal stage. "The small size of the emerged moths and the low number of eggs (on an average, 140) was conspicuous. The number of eggs in the less infected areas of the forest rose to 325. In 1955, the high average number of eggs (747) in the noninfected regions and the great egg masses on the trunks of some trees give rise to the conclusion that damages in 1956 will be still more considerable. The collapse of the gradation in the defoliated areas was only local and did not influence the outbreak of the gypsy moth, taking the forest as a whole . . . [This] is confirmed by the very low degree of parasite activity, which is also a characteristic feature of a gradation before it reaches its peak.
**Adults: 13; Generation: 4; Larvae: 7**

512. Tadić, M. D.
1959. **Numerical frequency of gypsy moth egg parasites *Anastatus disparis* R. and *Ooencyrtus kuwanae* How. in some localities of the P.R. of Macedonia in 1958–59** [in Serbo-Croatian, English summary]. Zast. Bilja 56: 27–31.

In individual and total gypsy moth egg clusters analyzed, there were a considerably greater number of eggs parasitized by *Ooencyrtus kuwanae* than by *Anastatus disparis*. By dissecting eggs it was found that in a single gypsy moth egg, two and even three imagos of *O. kuwanae* can develop.
**Eggs: 4**

513. Tadić, M. D.
1962. **A contribution to the knowledge of the diapause of the gypsy moth egg parasite *Anastatus disparis* R. on the island Hvar** [in Serbo-Croatian, English summary]. Zast. Bilja 63/64: 13–19.

In Yugoslavia *Anastatus disparis* remains in the state of diapause for 1 year. On the island Hvar, the life cycle of *A. disparis* varies from that in the rest of Yugoslavia. In 1957, 91,237 gypsy moth eggs from Hvar were analyzed. Of these, 7.6 percent were parasitized by *A. disparis*; 31.5 percent of the parasites emerged in the same year as oviposition, and 68.5 percent emerged in the year following oviposition. A possible explanation of this phenomenon is the difference in climate between Hvar and continental Yugoslavia.
**Eggs: 4**

514. Tallós, P.
1966. **Forecasting damage by *Lymantria dispar* L.** [in Hungarian; Russian and German summaries]. Erdo 15(12): 549–552.

515. Telenga, N.A.
1929. **Hymenopterous parasites of the family Ichneumonidae reared at the Kubanj plant protection station in 1927** [in Russian]. Zashch. Rast. (Leningrad) 6(1–2): 225–226.

Ichneumonid parasites reared from lepidopteran pests, including the gypsy moth, are listed. Three species reared from insects other than the gypsy moth are described. Those reared from the gypsy moth are: *Pimpla instigator* F. (which is also reared from *Euproctis chrysorrhoea* L., *Malacosoma neustria* L., and *Pieris brassicae* L.) and *Theronia atalante* Poda, which is reared only from gypsy moth pupae.
**Pupae: 4**

516. Tempel, W.
1939. **A mass occurrence of Asopinae (Hemiptera: Pentatomidae)** [in German]. Arb. Physiol. Angew. Entomol. Berlin-Dahlem 6(1): 51–56.

517. Templado, J.

1957. **Data on *Ooencyrtus kuwanai* How., a chalcidid parasitic on *Lymantria dispar* L. in Spain** [in Spanish]. Publ. Inst. Biol. Apl. Barcelona. 25: 119–129.

*Ooencyrtus kuwanai* was introduced into Spain 30 years ago, but in an oak forest of central Spain, not more than 20 to 25 percent of the eggs of gypsy moth are parasitized. Competition with the indigenous *Anastatus disparis* is slight; *A. disparis* parasitizes about 15 percent of the eggs. Its propagation is recommended, especially for oak forests in areas having a mild winter climate.

**Eggs: 4**

518. Templado, J.

1965. **Goldschmidt's work on *Lymantria dispar* and his opposition to neo-Darwinism** [in Spanish]. Bol. R. Soc. Esp. Hist. Nat. Secc. Biol. 63: 185–192.

519. Thompson, W. R.

1923. **A criticism of the "sequence" theory of parasitic control.** Ann. Entomol. Soc. Am. 16: 115–128.

The sequency theory, as stated by Fiske (1910), is that a sequence of parasites attack a particular host in different stages of its development, resulting in a stable host population. While a sufficient number of parasites are temporarily separated so as to fit the concept to the gypsy moth, the theory does not hold because the gypsy moth population density fluctuates considerably. The sequence theory rarely applies to natural systems because the parasite:host population equilibrium is so delicate.

**Generation: 4**

520. Thompson, W. R.

1923. **On determining winglessness of an ichneumonid parasite (*Pezomachus sericeus* Forst)** [in French]. Bull. Soc. Entomol. Fr. 1923(3): 40–42.

521. Thompson, W. R.

1946. **A catalogue of the parasites and predators of insect pests.** Sec. 1. Parasite host catalogue. Part 8. Parasites of the Lepidoptera (N-P). Imperial Parasite Service, Belleville, Ontario, Can.

Lists (pages 490–500) parasites and predators of *Porthetria dispar* (L.) and *P. dispar japonica* Mats., giving binomial names, author, order, family, and sites where reported.

**Generation: 3,4,13**

522. Tichý, V.

1962. **The influence of birds on the gradation of some injurious insects** [in Czechoslovakian, English summary]. Sborník prednásek II. celostátní konference Ceskoslovenské spolecnosti v Praze. Praha 1962. 166: 129–137.

The influence of the density and diversity of bird populations on all developmental stages of forest insect pests is examined. From wintertime until the time the pest *Bupalus piniarius* reached larvae stage, bird density increased 308 percent. At the climax of the gradation, the chaffinch concentration increased 19-fold. Of a total of 67 bird species found, 14 were nesting, and 34 were observed feeding on the pest. *Parus major* consumed all stages of the insect; *Fringilla coelebs* consumed all but pupae. When gradation was at climax, 2.1 percent of eggs, 13.6 percent of larvae, and 14.7 percent of pupae were consumed by birds.

Schwenke's assumption (Beitr. Entomol. 1952) is that there is a 10 percent decline of larvae due to birds under normal conditions. In an infestation of *Tortrix viridana* and *T. loefflingiana* leafrollers, 121 species of birds were found, of which 37 dominant species constituted 90 percent of the population. Comsumption of leafroller was ascertained in 58 species, primarily by starling (*Sturnus vulgaris*), great tit (*Parus major*), chaffinch (*Fringilla coelebs*), tree sparrow (*Passar montanus*), blue tit (*Parus coeruleus*), great spotted woodpecker (*Dendrocopus major*), white throat (*Sylvia communis*), chiffchaff (*Phylloscopus collybita*), and willow warbler (*P. trochilus*). Together, they consumed only 3 to 4 percent of the insects. In depredations showing great oscillations, the absolute number of insects consumed by birds rises with the advance of gradation, but the percentage falls. "Not even where the pest was strongly overpopulated was it possible to observe the so-called overfeeding with unilateral food as is often adduced in literature."

**Larvae: 2,9**

523. Tinbergen, L.

1960. **The natural control of insects in pine woods. I. Factors influencing the intensity of predation by songbirds. Arch. Neerl. Zool. 13: 265–343.**

The role of birds in regulating insect numbers is examined. Research is limited to Scots pine woods in the spring and summer brood season. The gypsy moth is not present, but two hairy caterpillars are *Lymantria monacha* L. and *Dendrolimus pini* L. Ninety-two broods were studied from 1948 to 1954: 67 great tit (*Parus major*), 13 blue tit (*P. coerculeus*), 7 crested tit (*P. cristatus*), and 5 coal tit (*P. ater*). Their hunting techniques are similar: Primarily visual clues are used; they take only prey which can be caught quickly; and rarely are these insects in flight. The blue tit is more likely to eat food in webs or galls. Adults may prepare large larvae before giving them to young by decapitating and plucking hairs. Moths may be brought wingless. Large larvae are more likely to be "prepared" than are small larvae. Older nestlings receive part of their food alive. It was found that *Lymantria* larvae averaged 5 percent of the food in late June and early July, with a maximum of 25 percent in early July 1951.

*Lymantria* were the largest larvae studied and were found to have the highest index of relative risk despite their cryptic behavior. Their size may compensate for their inconspicuousness, since birds actively search hiding places once it is known that these larvae are in the area. Synchronization of the life cycles of many species lowers the risk factor for all. There are marked differences in the oscillations. Percentage of predation falls steeply where there is high host density, because the bird density remains constant and because birds vary their diet and avoid more numerous species.

**Generation: 2,4,9; Larvae: 9**

524. Tomić, D.

1952. **A study of the influence of elevated temperatures and submergence in water on gypsy moth eggs** [in Serbo-Croatian, French, summary]. Glas. Sumar. Fak. Univ. Beogradu 5: 221–242.

525. Tothill, J. D.

1916. **The introduction and establishment in Canada of the natural enemies of the brown-tail and gipsy moths.** Agric. Gaz. Can. Ottawa. 3: 111–116.

As of 1916 the gypsy moth had not yet reached Canada but was expected to cross the international boundary within a few years. It was not known if climatological conditions would stop its northward expansion or if the insect would find a niche in the boreal forests. As a preventative measure, insect parasites and predators were imported to create a living barrier to prevent the northward spread of the gypsy moth.

**Generation: 3,4.**

526. Townsend, C. H. T.

1908. **A record of results from rearings and dissections of Tachinidae.** U.S. Dep. Agric. Bur. Entomol., Tech. Ser. 12, Misc. Pap. 6: 95–118.

A wealth of information is presented on the life histories and methods of rearing tachinid parasites. Five different styles of reproductive habits were observed: host-oviposition, leaf-oviposition, supracutaneous host-larviposition, subcutaneous host-larviposition, and leaf-larviposition. Conclusions can be drawn as to the type of reproductive habit by studying uterine eggs. For example, the thickness of the shell indicates whether it will hatch within the uterus, and chitinization indicates that it is made to withstand exposure following leaf-oviposition. It is concluded that *Blepharipa scutellata* and *Crossocosmia* sp. are important parasites of *Porthetria dispar* because of their great capacity for reproduction and because of their leaf-oviposition, which creates a situation in which all of their eggs must be eaten by the larvae whenever the gypsy moth is abundant.

**Larvae: 4**

527. Treyman, F. S.

1938. **The number of caterpillars hatched from eggs of the gypsy moth and their survival at an early age depending on the feeding conditions of the maternal generation** [in Ukrainian; Russian and English summaries]. Acad. Sci. Ukr. SSR. Rep. Inst. Zool. Biol. 5: 117–144.

Pupal weight, which depends on the quantity of food, affects not only the number of eggs laid but also the quality, and is closely connected with vital activity of the succeeding generation. Females emerging from pupae with greater weight yield egg clusters having a greater weight. In this study, large egg clusters had 84 percent hatched eggs, while smaller clusters only had 41.5 percent hatched eggs. The lower the pupal weight, the

higher the percentage of eggs and larvae perishing in the first and second instars. The average percentage of larvae perishing in the first and second instars was the same, however, whether the larvae came from eggs of a starving generation or from eggs of an abundantly fed generation. Nutritional conditions of the preceding generation affected the weight of the pupae of the daughter generation, although the larvae of the latter were fed equally. Prolonged and intense starvation of larvae produced very low-weight pupae which became sterile adults.
**Adults: 13; Eggs: 13; Fecundity: 13; Larvae: 13; Pupae: 13**

528. Tsap, L.I.
1965. **A study of most of the pests of oak forests in the Crimea** [in Russian]. Lesovod. Agrolesomelior. 6: 103–107.

529. Tschorbadjiew, P.
1925. **Report on research on the parasites of destructive insects in Bulgaria** [in German, Bulgarian title]. Bulg. Entomol. Druzh. 2: 84–9.

530. Tuleschkov, K.
1935. **On the causes of hibernation in the egg stage of *Lymantria dispar*, *L. monacha*, and other Lymantriids** [in German]. Z. Angew. Entomol. 22(1): 97–117.

531. Turček, F. J.
1948. **Birds in an oak forest during a gypsy moth outbreak in South Slovakia.** Am. Midl. Nat. 30(2): 391–394.
During a large gypsy moth outbreak in South Slovakia, the density of certain species of birds doubled or tripled. Nine species were seen eating larvae. The golden oriole (*Oriolus oriolus oriolus*), the hawfinch (*Coccothraustes coccothraustes*), and the starling (*Sturnus vulgaris vulgaris*) were the most important. The author hypothesized that the effect of birds on the gypsy moth population is to prolong the period between outbreaks.
**Larvae: 9**

532. Turček, F.
1950. **The bird population in some deciduous forests during a gypsy moth outbreak** [in Czechoslovakian; English and Russian summaries]. Bull. Inst. For. Res. Czech. Repub. 3: 108–131.
Because of defoliation, nesting success in outbreak areas is very low. Therefore, the effect of birds on the gypsy moth population depends on a daily influx of birds from surrounding areas. During an outbreak, birds eat a maximum of 2 percent of the larvae. Birds probably play a role in maintaining gypsy moth populations at innocuous levels but are of little consequence at outbreak densities.
**Generation: 9**

533. Turchinskaya, I.A.
1963. **Effect of leaf eating by the gipsy moth and other leaf-eating insects upon the growth of the oak** [in Russian, English summary]. Zool. Zh. 42(2): 248–255.
"Investigations carried out in Savalsk forest management, Voronezh region, in 1958–1961 found that the eating of leaves by such pests as the gypsy moth, green tortrix moth, water moth, and notodid did not lead to a dying of the oak groves even in cases when the mass outbreaks of these insects are of 2 to 3 years' duration. The decrease in growth in the stands damaged is different, fluctuating within a broad range . . . from 15 to 65 percent . . . [of] the growth of the same trees in . . . previous years without . . . damage to the foliage, [and] when weather conditions were similar. The loss of the foilage in the early spring and in summer affects tree growth in diameter in the same way. The damage . . . [to] leaves in summer is of no considerable importance to the growth of the trees in height."
**Oak stands: 15,24**

534. Turner, N., ed.
1963. **Effects of defoliation by the gypsy moth.** Conn. Agric. Exp. Stn. Bull. 658. 30 p.
The ". . .purpose of the study was to determine the effect of heavy defoliation by the gypsy moth in 1953 and 1954 on white pine survival and growth rates." The degree of initial defoliation and subsequent death or extent of recovery over a 5-year period was recorded. Conditions of the study involved a single defoliation and normal weather. Results: 100 percent defoliation by the gypsy moth resulted in 28 percent mortality of white pine, 74 percent of hemlock, and 5 percent of oaks; 90 percent defoliation caused mortality in 8 percent of white pine, 9 percent of hemlock, and 6 percent of oaks. Less than 90 percent defoliation caused little mortality and trees recovered within 5

years. Greatest mortality in white pines occurred in the second year after 100 percent defoliation, with appreciable amounts in the other 4 years; virtually all mortality of hemlock occurred the year following defoliation. Mortality of overtopped pines was greatest, but hemlock mortality was greatest in dominant and intermediate crown classes. Evidence of extensive killing of white pine is lacking, probably because of the rapid disappearance of pine after death.

**Oak stands: 24; Non-oak stands: 15, 24, 26**

535. U. S. Department of Agriculture, Forest Service and Animal and Plant Health Inspection Service.
1974. **Final environmental statement: cooperative gypsy moth suppression and regulatory program, 1974 activities.** 178 p.

This environmental impact statement reviews and synthesizes research material on the impact of the gypsy moth on trees, forest resources, and people. It evaluates the effect of various proposed control mechanisms. Reviews of the statement are included in the appendix.

**Review; bibliography**

536. U. S. Department of Agriculture, Forest Service and Animal and Plant Health Inspection Service.
1975. **Final environmental statement addendum to the final 1974 gypsy moth environmental statement.** 31 p.

This report contains a description of the present situation, results of 1974 suppression and regulatory activities, new information on pilot control projects (economic considerations, insecticide tests, and pertinent research results), proposed suppression projects, and a proposed regulatory program. It also contains comments from reviewers.

**Generation: 1**

537. Vaclav, V., E. Georgijević, and D. Lutešek.
1959. **Stationary researches in the dynamism of the gypsy moth population: localities where no control actions against the gypsy moth are undertaken (1958)** [in Serbo-Croatian, English summary]. Zast. Bilja 52/53: 61–72.

Ten localities in Herzegovina were investigated. Various indicators showed that the gypsy moth was in retrogradation in all of them.

**Generation: 2**

538. Vaclav, V., E. Georgijević, and D. Lutešek.
1959. **Problem of gypsy moth focuses in Bosnia and Herzegovina (*Anastatus disparis* Ruschka as indicator of gypsy moth localities)** [in Serbo-Croatian, English summary]. Zast. Bilja 52/53: 73–78.

The problem of gypsy moth foci in Bosnia and Herzegovina has been dealt with for 2 years. The specific egg parasite of the gypsy moth, *Anastatus disparis,* can indicate the foci. Last year analysis of gypsy moth eggs from 127 localities was conducted and "*A. disparis* was discovered in egg clusters from 14 localities. In 1958 the analysis of gypsy moth clusters with reference to egg parasites was carried out in 52 localities, and *A. disparis* was observed in 24 localities. This egg parasite appeared in the course of two consecutive years on the same terrains of Forest Administration Districts Trebinje, Bileća, Čapljina, Mostar, and Listica. It is likely that the south and southwest regions of Herzegovina . . . are a part of the gypsy moth's wider territory which also occupies the neighboring regions of the Middle and South Dalmatia near Čapljina, Ljubuški, and Trebinje as well as Montenegro near Bileće." Investigation of gypsy moth foci should continue into the latent period of the moth with the presence of *A. disparis* serving as an indicator of foci.

**Eggs: 4; Generation: 2**

539. Vago, C., and P. Atger.
1961. **Massive multiplication of insect virus during the pupal moult** [in French, German summary]. Entomophaga 6(1): 53–56.

540. Vago, C., J. Fosset, and M. Bergoin.
1966. **Dissemination of polyhedral virus by the *Ephippiger,* predators of insects** [in French, English summary]. Entomophaga 11(2): 177–182.

"Transmission of polyhedral viruses by *Ephippiger bitterensis* having ingested virus-diseased *Lymantria dispar* larvae was observed in nature and in experiments. The passage of polyhedral bodies in different parts of the gut was studied by histological methods, and the effect of the gut juice was found insignificant. These bodies were detected in dejections during 15 days after ingestion of diseased insects. Viruses were shown by electron microscopy and [by] the confirmation of

their pathogenic effect by infection tests. The significance of these results in epizootiology and in biological control is discussed."
**Larvae 3, 7**

541. Valentine, H. T. and R. W. Campbell.
1975. **A simulation model of gypsy moth/forest interaction.** For. Sci. 21: 233–238.
"A model developed from data collected in New England simulates the behavior of the gypsy moth (*Porthetria dispar* (L.))—forest system in many stands and over many years, yielding estimates of future egg mass density, defoliation, tree condition, and tree mortality. It will also yield frequency distributions of expected egg mass density and defoliation levels for one stand in 1 year. This information may be valuable to decision-makers concerned with regulating gypsy moth infestations."
**Generation: 2, 12; Oak stands: 15, 20, 25; All stands: 15, 20, 25, 26**

542. Varga, F.
1968. **New nutritive-biological examinations related to the gypsy moth (*Lymantria dispar* L.)** [in Hungarian, Russian, German, English summaries]. Erdezeti Faipari Egy. Tud. Kozl. 1: 129–141.
The author raised larvae of the gypsy moth on several plants at a temperature of 18 to 23° C. The purpose of the experiments was to decide whether the larvae were amenable to mass reproduction. The plants were: white poplar, black poplar, balsam poplar, *Populus euramericana* cv., *marilandica,* European oak, Austrian oak, and *Robinia.* The results showed that the leaves of white poplar, balsam poplar, and *Robinia* lack food value for the gypsy moth. The leaves of *Populus euramericana* cv. *marilandica* and black poplar are the two main nutritive plants of the gypsy moth. Leaves of European oak and Austrian oak have the same food value as the former two.
**Oak stands: 23; Larvae: 1, 12; Non-oak stands: 23**

543. Vasić, K.
1950. **Contribution to the knowledge of the cause of disruption in the sexual index in the critical-eruption stadium in the gypsy moth's development** [in Serbo-Croatian, French summary]. Glas. Sumar. Fak. Univ. Beogradu 1: 311–336.
Sex ratio is determined by abiotic and biotic factors after larval emergence. This depends not only on the higher susceptibility of one sex to these factors but also on selection for one sex or the other by parasites. Criteria for pre-eruptive and eruptive stages are given.
**Sex ratio: 2,4,7,12**

544. Vasić, K.
1950. **Results of an examination of the pupae of *Lymantria dispar* L. in 1948** [in Serbo-Croatian, French summary]. Zast. Bilja 2: 25–34.

545. Vasić, K. and L. Janković.
1958. **A contribution to the knowledge of indicators for the prognostication of the evolution of the gypsy moth gradation** [in Serbo-Croatian, English summary]. Zast. Bilja 41/42: 3–15.
The stage of the gypsy moth gradation can be determined using fundamental and complementary indicators. Fundamental indicators are determined in the field and include number of clusters per square unit, number of clusters per tree, and number of trees infested with clusters. The significance of these numbers depends on the age of the biotope. Middle-aged forests have more food available, and thus it takes more clusters to seriously damage the trees.
Other fundamental indicators are: (1) Place where the clusters are deposited, since in latency in the lowlands and throughout the gradation in hills and mountains, egg clusters are hidden. The beginning of the gradation is characterized by deposition of visible clusters, especially on the lower tree trunk. As the gradation progresses, the height of oviposition increases and eggs are laid in various places—shrubs, leaves, branches, stones, etc. (2) Size and shape of the clusters, with large-sized clusters indicating pre-eruptional stages and small to medium clusters indicating a posteruptional year. (3) Polyphagy of larvae which increases in the course of the gradation. (4) Larval migration, which indicates the eruptional stage. (5) Number of pupae per pupal cluster, which increases from one to several score in the course of the gradation. (6) Predators which appear as the numbers of larmae increase. (7) Polyhedrosis, which cannot be used with certainty as a prognosticative sign of the reduction of gypsy moth numbers since it appears sporadically.

Complementary indicators include: (1) Number of eggs in clusters, which decreases with the numerical increase of the population. (2) Number of fertilized eggs, which increases with the progress of the gradation and which is far less in the lowlands than elsewhere. (3) Duration of hatching period, which draws out as the gradation nears its end. (4) Percentage of hatched larvae, which starts out very high and decreases rapidly in the posteruptional stage. (5) Percentage of parasitism, which gradually increases so that the number of parasites becomes almost equal to the number of hosts in the eruptional stage. (6) Sex ratio, which is normal in the beginning but then shifts to a prevalance of males, one of the unfailing signs of the imminent end of the gradation. (7) Fecundity and fertility, both of which decrease in the course of the gradation.

**Eggs: 2; Fecundity: 2; Generation: 2,3,4,7,12; Larvae: 1,2; Pupae: 1,2; Sex ratio: 2**

546. Vasić, K., and L. Janković.
1958. **Results of investigations of gypsy moth clusters on the territory of Yugoslavia in 1957** [in Serbo-Croatian, English summary]. Zast. Bilja 41/42: 147–155.

Gypsy moth egg clusters were collected from all over Yugoslavia and evaluated for size and shape, average number of eggs, and percentages of fertilized eggs, parasitized eggs, and hatched larvae. Using these characteristics, the authors predicted the condition of the gradation in different parts of Yugoslavia. In most localities in Serbia, Montenegro, and Bosnia-Herzegovina, the gypsy moth was in retrogradation and the egg clusters were scare, small, of irregular shape, and with few eggs. However, a great number of large, normally shaped clusters were found in areas in Serbia where the gradation had passed culmination 2 to 3 years previously. In Croatia and Macedonia some of the cluster characteristics indicated the culmination stage. The gypsy moth frequently appears in exactly those places where chemical control had been used earlier.

**Generation: 2**

547. Vasić, K.
1958. **Comparative analysis of the respective courses of the gypsy moth gradation in the intervals 1946–1950 and 1953–1957** [in Serbo-Croatian, English summary]. Zast. Bilja 49/50: 9–22.

Climatic conditions in four localities observed during the gradations were analyzed and graphically related to gypsy moth population density. The climate during the 1946–1950 gradation was warmer and considerably drier than during the 1953–1957 gradation. Temperature showed a slight, though constant, decrease during both gradations in all investigated places. This correlates with laboratory experiments which showed that the gypsy moth has the highest biological potential at temperatures below 20°C. No conclusions were drawn regarding precipitation, except that during the more humid second gradation, the gypsy moth favored the warmer and drier regions of East Serbia. Also in the second gradation, there were two numerical maxima in several places, because the propagation did not oversatiate the capacity of the biotope, and because parasitic action was inhibited by the cold and rainy climate. Starvation was a more important factor in the first gradation, which extended over wider areas and had higher densities in individual biotopes. The polyhedry, of little importance in the first gradation, was in many places the major factor of crisis in the second gradation. The principal lines of the two gradations were similar: a slow increase in the 2-year preparatory phase, a precipitous rise in the prodromal year, a 40-fold increase between the prodromal and preeruptional years, and a 270-fold increase to the eruptional-critical year.

**Generation: 2,12; Larvae: 4**

548. Vasić, K., and P. Sisojević.
1958. **Parasites of pronymphs and pupae of the caterpillar in Yugoslavia in 1957** [in Serbo-Croatian, English summary]. Zast. Bilja 41/42: 49–52.

Prepupae and pupae were collected in great numbers in 1957, at the crisis of the gradation, and reared for parasites. Various species of Sarcophagidae were most numerous; Tachinidae and Hymenoptera were also found. Of the tachinids, *Blepharipoda scutellata* R.D. was the most numerous (80.6 percent), followed by *Phorocera agilis* R.D. (16.7 percent), and *Compsilura concinnata* Meigen (1.2 percent). *Carcelia excisa* v. *separata* Rond., *Drino inconspicua* Meigen, and *Exorista larvarum* L. totaled 1.5 percent. Among Ichneumonidae were *Ichneumon disparis* Poda (30.6 percent), *Theronia atalantae* Poda (63.9 percent), and *Pimpla examinator* F., *P. rufata* Gm., and *P. instigator* F. (5.5 percent). The family Chalcididae

were represented as hyperparasites on 7.5 percent of parasites.
**Prepupae: 4; Pupae: 4**

549. Vasić, K.
1958. **Parasitic hymenoptera of gypsy moth** [in Serbo-Croatian, English summary]. Zast. Bilja 41/42: 17–21.

Parasitic hymenoptera have not been found to be of great importance in reducing gypsy moth populations. An exception to this is species of the genus *Apanteles* which infrequently cause a crisis of the gradation. Ichneumonidae, except for *Hyposoter disparis* Viel and to a certain degree *Theronia atalanta* Poda, are either very rare parasites or hyperparasites (*Hemiteles* spp.) of the gypsy moth. All observed Chalcididae species are hyperparasites. A list is given of ichneumonids, braconids, and chalcids which have been reared from eggs, larvae, or cocoons of the gypsy moth.
**Generation: 4**

550. Vasić, K., and S. Salatić.
1959. **A new contribution to the knowledge of the parasitic hymenoptera of the gypsy moth: parasitic hymenoptera of the gypsy moth in 1958** [in Serbo-Croatian, English summary]. Zast. Bilja 52/53: 45–50.

In addition to *Anastatus disparis* Ruschka, an autochthonous egg parasite of the gypsy moth, *Ooencyrtus kuwanai* How., an imported species, was observed. It was previously limited to a few localities in the warmest regions of Macedonia (Strumica and Stip). The percentage of parasitized gypsy moth eggs collected in autumn of 1957 was very low for both parasite species observed. The clusters containing fewer eggs were parasitized at the highest rate. It was also established that parasitism was highest where the gypsy moth was in its numerical culmination or in the first year of the retrogradation. The sex ratio in the populations of *A. disparis* was quite variable, but its value in localities with a small percentage of parasitized gypsy moth clusters was approximately normal (about 0.5). However, in localities where parasitism was higher, the ratio of males in the population was increased. Of the larval parasites, only *Apanteles melanoscelus* Ratzb. and *A. solitarius* Ratzb. were observed. The total percentage of parasitism by both these species varied at Jakovački Ključ (region of Srem) from 1.6 to 6.6 percent. Parasite cocoons were found only in May. The parasites of the prepupae and pupae were examined only on material from Macedonia. The only species observed was *Theronia atalantae* Poda. Four more species of hyperparasites were found, three on the pupae of tachinids (*Phygadeuon variabilis* Grav., *Brachymeria minuta* L., and *Perlampus ruficornis* F.) and one on the cocoons of *Apanteles Liparidis* Bouché ( *Hemiteles fulvipes* Grav.).
**Eggs: 4; Generation: 4; Larvae 4; Pupae: 4**

551. Vasić, K., L. Janković, and P. Sisojević.
1959. **Indicators for the prognostication of gypsy moth gradations** [in Serbo-Croatian, English summary]. Zast. Bilja 52/53: 181–183.

In 1958 work was continued to establish indicators for the prognostication of gypsy moth gradations. Particular attention was paid to the investigations of the density of egg clusters in various biotopes, places where eggs were deposited, number of eggs in the clusters, size and dimensions of clusters, percentage of larvae hatched in the wild and in the laboratory, and percentage of parasitism in each developmental stage.
**Generation: 2**

552. Vasić, K., M. Maksimović, M. Dordević, J. Ivanović, and V. Stanić.
1959. **Investigations in the diapause of the gypsy moth** [in Serbo-Croatian, English summary]. Zast. Bilja 52/53: 161–162.

Duration of diapause was considerably reduced when eggs were kept at 14 to 15 °C after embryonic development was completed. Differences were established in the duration of diapause with insects reared at various temperatures. Oxygen consumption during embryonic development and diapause were analyzed, as were the embryo-histological changes during diapause.
**Eggs: 12,13**

553. Vasić, K., and L. Janković.
1960. **A contribution to the knowledge of characteristics of the indicators for the condition of gypsy moth populations in latency** [in Serbo-Croatian, English summary]. Zast. Bilja 56: 39–44.

Detailed studies of the gypsy moth were started in 1953, at the beginning of the last gradation, so that only a limited amount is known about indicators of the latent phase of the gradation. The number of clusters is very small, varying from 2 to

60/ha, showing that the population density oscillates during latency. The number of eggs per cluster is rather large, averaging 700. This number decreases as the number of clusters per square unit increases. The number of unfertilized eggs is small, as is the case during the first years of progradation. During latency, clusters are usually deposited in hidden places, but in damp forests they are laid in conspicuous places as well. Most are deposited below 50 cm. Clusters are of normal form—oval and pear-shaped; round forms occur when the female has limited space. Large and medium-sized clusters are most frequent. The number of larvae hatching from clusters differs considerably under identical conditions.

**Adults: 1; Fecundity: 2; Generation: 2**

554. Vasić, K.

1972. **A biological method of control of *Lymantria dispar* L. and *Diprion pini* L.** Final Technical Report, Project No. E30–F59, Grant No. FG–YU–120. Institute of Forestry and Wood Industry of Serbia, Beograd, Yugoslavia.

This report covers the results of three separate investigations pursued over a 5-year period, all concerned with the question of biological control of injurious forest insects. The first involves the gypsy moth predator *Calosoma sycophanta* L., the second is about *Apanteles* parasites of early-instar gypsy moth larvae, and the third is on the sawfly parasite, *Neochrysocharis ruforum* Krausse.

The population dynamics of *C. sycophanta* are closely related to the population level of the gypsy moth. When the gypsy moth enters the latent phase of its gradation, *Calosoma* enters a perennial diapause, during which time the imagos remain in their hibernation cells. The predator has two types of diapause, trophical and sexual. The first is unstable and can be forcibly interrupted with ease, whereas the latter is stable and lasts 3 to 4 years. Individual imagos become trophically activated during the diapause, go to the surface and eat a small amount of food, then return underground and resume hibernation. This feeding allows them to survive long periods of prey latency. It is conceivable that an abundance of prey prolongs the trophical activity, which in turn causes reproductive activity. The predator population becomes trophically activated during the progradation of the prey and reproductively activated during the preculminative and culminative stages of the prey. During the course of investigations on *Apanteles* spp., a method of rearing large numbers of them in the laboratory was perfected. *A. porthetriae* Muesb. and *A. melanoscelus* are the species most widespread in Yugoslavia, the latter being of great importance in oak forests. *A. solitarius*, which is thought of as primarily a parasite of *Leucoma salacis*, was frequently found to parasitize the gypsy moth in poplar forests on the plains. *A liparidis*, the only gregarious species involved with the gypsy moth, was predominant in northwest Yugoslavia. These wasps are most effective in light, warm areas, rather than in dense forest.

**Instars I–III: 4; Larvae: 3; Pupae: 3**

555. Vasiljević, L.

1958. **Influence of the temperature oscillations in the nature upon the development of the polyhedry among gypsy moths** [in Serbo-Croatian, English summary]. Zast. Bilja 41/42: 57–66.

In the course of larval studies in Serbia, May 25 to July 1, 1957, four periods of high larval mortality due to virus were conspicuous. Each of these high-mortality periods was preceded by a period of high maximum temperature followed by an incubation period of 1 to 4 days, the duration depending on how high the temperature rose during the heat spell. High daily temperature in the course of the gradation exerted a favorable influence on the development of a polyhedrosis epizootic. In regions where climatic conditions were not as favorable to the development of polyhedry, the gypsy moth numbers remained high.

**Larvae: 7,12**

556. Vasiljević, L.

1958. **Share of the polyhedry and other diseases in the reduction of the gypsy moth gradation which took place in the PR of Serbia in 1957** [in Serbo-Croatian, English summary]. Zast. Bilja 41/42: 123–137.

An epizootic caused by polyhedrosis virus occurred in Serbia, June 15 to June 20, 1957. In the regions where the gypsy moth was in gradation, three classifiable intensities of the epizootic were noted: (1) Gently sloping hillsides with southern exposure, dry air, and high maximum daily temperatures had the highest intensity epizootic with complete destruction of the gypsy moth. (2) Medium lowlands without excessively high daily temperatures and with moderate humidity had a lower intensity epizootic, which did not destroy the gypsy moth population completely. (3) Mountain

stream valleys with high relative humidity, and without high maximum daily temperatures, rarely or never had polyhedrosis epizootics, and probably serve as foci for maintaining the gypsy moth in latency. Of other gypsy moth diseases, *Beauveria* spp. mycosis was found to relate to precipitation during pupation, but not to relative humidity of the air; *Nosema lymantriae* Weiser caused protozoonoses in a small number of larvae and pupae; and bacterioses were scarce and appeared to be chiefly associated with virus diseases. Parasitization of larvae and pupae was very great in most regions and in many places acted in concert with the polyhedry to complete the gypsy moth gradation.

**Generation: 4,5,6,7,8**

557. Vasiljević, L.
1959. **The appearance of polyhedry in the gypsy moth during the first year after the end of massive population** [in Serbo-Croatian]. Zast. Bilja 52/53: 79–87.

Death from polyhedrosis virus occurs at all stages of gradation. A dense population of insects is not necessary to cause death from virus in individuals. In both field and laboratory studies, it was found that death due to virus continues in the first year after the end of the outbreak. In the gypsy moth, the infection usually starts at the beginning of pupation, especially with females, which have a longer developmental period. Moths of diseased larvae lay infected eggs, which is the reason for continued mortality from virus in a scarce population. The percentage of larvae dying from virus varies with the stage of gradation, the polyhedrosis playing a much smaller role in the reduction of numbers after the end of the outbreak. The condition of the eggs over the winter affects the percentage of survival from virus infection. Some researchers believe a resistance to polyhedry builds up after an epizootic which prevents another epizootic even though the insect population has again become dense.

**Adults: 7; Eggs: 7; Generation: 2; Larvae: 7; Pupae: 7**

558. Vasiljević, L.
1959. **Density of gypsy moth populations in various localities of the PR of Serbia in the first year after the epizootic diseases of the polyhedry type** [in Serbo-Croatian, English summary]. Zast. Bilja 52/53: 167–171.

A gypsy moth gradation in Serbia was brought to a halt in 1957 by a virus epizootic. In this study, the relation between the intensity of the disease in 1957 and the population density in 1958 was correlated with the climatic and geographic conditions in various localities. It was found that the epizootic reduced the gypsy moth population in Serbia unevenly; that the gypsy moth was still present in all localities where it had been during the gradation; that the population density the year following the epizootic was closely connected with the intensity of the epizootic; and that the year after the epizootic the density was greatest in those locations characterized by "an agreeable freshness of air during the summer droughts." These locations are usually in the valleys of river mountains and have high humidity.

**Generation: 2,7,12**

559. Vasiljević, L.
1959. **Two years' fluctuation of the gypsy moth population after the end of the epizooty of the polyhedry type in some regions of the PR of Serbia** [in Serbo-Croatian, English summary]. Zast. Bilja 56: 75–78.

"During 1959, control of the flight of gypsy moths in several regions of the PR of Serbia was observed where an epizootic of polyhedrosis had occurred in caterpillars in the field in 1957. It was established that in most of these regions more . . . [moths] had been caught in the course of 1959 than in the course of the previous year. . . . Further checking of the population density will show whether the gypsy moth is already in progradation or still in latency in these regions."

**Generation: 2; Larvae: 7**

560. Vasiljević, L.
1961. **Influence of various phases of gradation upon the susceptibility of gypsy moth larvae to polyhedrosis** [in Serbo-Croatian, English summary]. Arh. Poljopr. Nauk. 45: 103–118.
Poljopr. Nauk. 45: 103–118.

The largest percentage of larvae killed by polyhedrosis virus came from a population in a state of culmination. Those most resistant to polyhedrosis were larvae from a population in a state of latency. Susceptibility of larvae in retrogradation and susceptibility of those reared in the laboratory represented a transition between the two previously mentioned groups.

**Generation: 2,7; Larvae: 7**

561. Vasiljević, L.
1961. **Susceptibility of gypsy moth larvae to polyhedral virus in nature during different phases of a population increase** [in French, English summary]. Entomophaga 6(4): 269–276.

"Experimental research was carried out to establish the polyhedral sensitivity of the caterpillars of *Lymantria dispar* L., in regard to their gradation phase in nature. Differences in polyhedral death rate after virus infection were revealed in relation to the culmination, the retrogradation, the latent phases as well as to an undetermined phase from which they originated. The possible reasons for this are . . . discussed."
**Generation: 7; Larvae: 7**

562. Vasiljević, L. A.
1962. **The infection of gypsy moth larvae by polyhedra of different ages** [in Serbo-Croatian, French summary]. Zast. Bilja 69–70: 107–114.

563. Vasiljević, L.
1964. **Susceptibility of the gypsy moth to the polyhedrosis in relation to duration of egg hibernation** [in Serbo-Croatian, English summary]. Zast. Bilja 15(80): 397–401.

In a laboratory experiment, it was shown that the longer gypsy moth eggs are in diapause the more susceptible the larvae that hatch from them are to polyhedrosis virus.
**Eggs: 7; Larvae: 7**

564. Vasiljević, L., and M. Injac.
1973. **A study of gypsy moth viruses originating from different geographical regions.** Plant Prot. 24(124–125): 169–186. (English reprint from Zast. Bilja.)

One gypsy moth gradation cycle in Yugoslavia usually lasts 8 to 9 years. The phases are: latency, progradation, culmination, and retrogradation. The chief factors controlling the sequence of gradation phases in Yugoslavia are parasites, predators, and polyhedrosis virus disease. At the time of a gypsy moth culmination, polyhedrosis involves 90 percent of the larvae just before pupation. It is even present in many pupae, preventing eclosion. Polyhedrosis is still present in the regression phase as a factor of population reduction, but in latency and progradation phases it is impossible to find gypsy moths killed by polyhedrosis. It was found that the same strain of larvae reacts differently to viruses from different geographical regions. One reason may be that larvae from different regions may not be in the same stage of gradation. Also there are definite differences in the pathogenicity of viruses from different areas.
**Larvae: 2,7; Pupae: 2**

565. Veber, J.
1956. ***Plistophora aporiae* n. sp., a parasite of *Aporia crataegi* L.** [in Czechoslovakian, Russian and German summaries]. Cesk. Parasitol. 3: 181–185.

566. Vives, J. L.
1959. ***Lymantria dispar* in cork plantations of our region** [in Spanish]. Mem. R. Acad. Cienc. Barcelona 1956 33(4): 49–60.

567. Vorontsov, A. I., and E. G. Mozolevskaja.
1972. **The effect of defoliators on the state and growth of oak woods.** Page 107 *in* Proc. 13th Int. Congr. Entomol., 1968., Nauk, Leningrad.

"Defoliation during different phenological periods causes various growth losses, their extent depending not only on the time of larval feeding, but on . . . habitat and [the] physiological state of the tree. Under the best conditions, where the period of oak growth is longer, most of the losses are caused by *O. dispar* and *Notodonta anceps* Goeze. Under less favorable conditions, where . . . oak growth begins and is reduced earlier, considerable growth losses are caused by *Tortrix viridana* L., *Operophtera brumata* L., and other early spring species. . . . Defoliation causes great changes in the ecosystem; it affects all elements (phytoclimate, soil, vegetation, and animal kingdom)."
**Oak stands: 15,17,19,23**

568. Vukasović, P.
1934. **On the invasion of gypsy moth larvae (*Lymantria dispar*) in the year 1934** [in Serbo-Croatian, French summary]. Arch. Minist. Poljopr. Yugosl. 1(2): 41–72.

569. Vukasović, P.
1936. **Contribution to the study of *Lymantria dispar* in 1935** [in Serbo-Croatian, French summary]. Arch. Minist. Poljopr. Yugosl. 3(4): 36–74.

570. Wallis, R. C.
1957. **Incidence of polyhedrosis of gypsy moth larvae and the influence of relative humidity.** J. Econ. Entomol. 50(5): 580–583.

This study indicates that the polyhedrosis virus has a latent stage which is transmitted through generations. The most important natural stress factor for manifesting virus appears to be humidity.

**Generation: 7**

571. Wallis, R. C.
1959. **Factors affecting larval migration of the gypsy moth.** Entomol. News 70: 235–240.

In laboratory tests it was found that larvae migrated toward moist sites only when responding to an interacting factor such as light, or when exhibiting the negative geotrophism of the early instars. "Middle- and late-instar larvae lost the geotrophic orientation and were distributed randomly regardless of the position of moist sites." When light was substituted for geotrophism as the interacting factor with moisture, young larvae were positively phototrophic and older larvae negatively phototrophic, regardless of the moist sites. When oak leaves were used as an attractant, it was found that the food alone elicited no migratory response, but that once food was encountered during random ambulatory movements or in the course of migration stimulated by other factors, the larvae accumulated on the leaves and fed. In tests conducted in darkness, young larvae exhibited a negative geotrophism, but when light was added the larvae migrated toward it no matter what direction it came from. Late-instar larvae did not migrate upward in the dark and lost their positive phototrophism. It was not clear from the experiments whether "this was a result of a loss of negative geotrophism and the development of an avoidance of light, or whether the larvae developed an avoidance reaction to the heat which was associated with light."

**Instars I–III: 1; Instars IV–VI: 1**

572. Wallis, R. C.
1960. **Environmental factors and epidemics of polyhedrosis in gypsy moth larvae.** Pages 827–829 *In* Proc. 11th Int. Congr. Entomol., 1960.

The most effective procedure for eliciting viral disease ". . . was utilization of excessive relative humidity at temperatures ranging between 80 and 85°F. The daily attack rate within a diseased colony was lowered by reducing the relative humidity within the rearing cage . . . It was [also] noted that larval migration and feeding were stimulated by reducing the humidity, whereas these activities were retarded under conditions of high humidity . . . During the 3- to 5-day period prior to feeding on foliage, [newly hatched larvae] were not susceptible to humidity changes, whereas older larvae were affected . . . At high temperatures, when metabolic activity was high, nutritional demand and feeding were at a maximum . . . [If there was an increase in relative humidity] without adequate air movement, the evaporation gradient between the caterpillar and its environment was lowered so that excess water ingested in the food could not be disposed of and feeding stopped—even though metabolic activity and nutritional demand were high. As a result, a secondary nutritional stress was incurred. At lower temperatures, when metabolic activity and subsequent nutritional demand were low, increased humidity and depression of the evaporation gradient did not result in such a stress."

**Larvae: 1,7,12,13**

573. Webber, R. T., and J. V. Schaffner, Jr.
1926. **Host relations of *Compsilura concinnata* Meigen, an important tachinid parasite of the gipsy moth and the brown-tail moth.** U. S. Dep. Agric. Bull. 1363. 31 p.

*Compsilura concinnata* emerges from its hibernating host in the spring as a last-stage larva. It pupates nearby, and after 10 days or so, the adult appears. This species is known to have many alternate hosts other than the gypsy moth and brown-tail moth, including 18 families of Lepidoptera among summer hosts. It uses little discrimination in its choice of hosts and will waste much effort in futile attacks upon unsuitable ones. *C. concinnata* habitually attacks only larvae that have reached the third stage. Owing to the gypsy moth's abundance, *Compsilura* attacks this species aggressively. In New England, there are two or more generations of *C. concinnata* on alternate hosts; the progeny of the second generation hibernate as larvae within Lepidopterous pupae.

**Larvae: 4**

574. Webber, R. T.

1932. ***Sturmia inconspicua* Meigen, a tachinid parasite of the gipsy moth.** J. Agric. Res. 45: 193–208.

This polyentomophagous parasite attacks the gypsy moth as well as the pine sawfly (*Diprion simile*). It overwinters as a larva in the pupa of a fly or a lepidopteran. Two generations are completed in the course of a year. Eggs are oviposited on the integument of the host.

**Larvae: 4**

575. Weiser, J.

1957. **Microsporidia of the gypsy moth and the nun moth** [in German, English summary]. Z. Angew Entomol. 40(4): 509–521.

"Two new microsporidians, which are described, were found infesting *Lymantria dispar* L. in Czechoslovakia. They are *Nosema lymantriae* and *N. muscularis*. A further microsporidian, *Thelohania similis*, was found in *Nygmia phaeorrhoea*. The course of the disease and the transference of the microsporidians to further secondary hosts in the same biotope show how closely the organisms are connected to the whole biozonose. This is also shown by the table of primary and secondary hosts of the individual microsporidians. It was found that two or more organisms can cause a mixed infection with combined symptoms. They can be isolated pure by transference to specialized secondary hosts. In one case, it was possible to infect a new host by mixing two microsporidians when one was not pathogenic to it in pure culture. Individual courses of epidemic processes, as known in human epidemiology, were found in the infection by microsporidians. In diseases of introduced pests, which they obtain in their new biozonoses, we can speak of natural sources of infection of these 'germs' in indigenous hosts, in the sense of Pavlovskij's theory."

**Generation: 8**

576. Weiser, J.

1963. **Protozoan diseases of the gipsy moth.** Pages 497–499 *in* J. Ludvík et al., eds. Progress in protozoology. Academic Press, New York.

A new species of protozoan *(Nosema serbica)* was named by Weiser. This protozoan attacks all the stages of the life cycle of the gypsy moth; transovarian transmission also occurs. Infected eggs usually hatch, but the larvae die before pupation. Larvae infected after hatching usually die as pupae or survive as adults, but the adult females are sterile. Occasionally adult females lay infected eggs which will hatch. Spread of the protozoan is dependent on gypsy moth density. The protozoan would not be useful as a spray for control but is useful for natural biological control. Owing to its density-dependent mechanism, the protozoan would help prevent severe outbreaks.

**Generation: 8**

577. Weseloh, R. M.

1972. **Field response of gypsy moths and some parasites to colored surfaces.** Ann. Entomol. Soc. Am. 65: 742–746.

Weseloh discusses the responses of the gypsy moth, of an egg parasite of the gypsy moth, *Ooencyrtus kuwanai* (Howard) (Hymenoptera: Encyrtidae), and of a parasite of the larvae of noctuids, Apanteles laeviceps Ashmead (Hymenoptera: Brachonidae) to differently colored surfaces. Stikem® -coated panels (white, yellow, red, blue, black, clear Plexiglas® and aluminum) were hung in two sites in Stonington, Conn. in the summer of 1971. "Numbers of insects caught varied according to species and date as well as color. *O. kuwanai* was attracted mainly to white and blue panels, *A. laeviceps* to clear Plexiglas panels, and gypsy moth males to red, blue, and black panels. The results are discussed as they relate to orientation in these organisms." Results may indicate that gypsy moth males tend to orient to dark objects, such as tree trunks, where females are likely to be located.

**Adults: 1, 13; Eggs: 4; Larvae: 1**

578. Weseloh, R. M.

1972. **Spatial distribution of the gypsy moth (Lepidoptera: Lymantriidae) and some of its parasites within a forest environment.** Entomophaga 17(3): 399–351.

"Aspects of the microhabitat distributions of the gypsy moth, *Porthetria dispar* (L.) (Lepidoptera: Lymantriidae), and some of its parasites were investigated in the field by means of sticky panels and gypsy moth egg masses exposed at different heights in trees, by egg masses exposed within forested and cleared areas, and by gypsy moth pupal collections from different heights in trees. *Ooencrytus kuwanai* (Howard) (Hymenoptera: Encrytidae), *Apanteles melanoscelus* Ratzeburg (Hymenoptera: Braconidae), and gypsy moths were caught most frequently on sticky panels

placed in upper portions of trees. In contrast, *Apanteles laeviceps* Ashmead, a parasite of cutworms, was most often caught near the forest floor. *O. kuwanai* attacked equally egg masses exposed at different heights in trees, but parasitized those in a clearing less often than those within the forest proper. *Brachymeria intermedia* (Nees) (Hymenoptera: Chalcididae) emerged mostly from pupae collected near the tops of trees and not at all from those collected below 5 m. The results are discussed as they relate to field sampling procedures, behavioral activities of gypsy moth and parasite adults, and integrated control possibilities for the gypsy moth." The distribution of adult males was monomodal with time. Males orienting to a strong pheromone source were active at lower levels of the forest than those not so orienting and presumably flying randomly.
**Adults: 1; Eggs: 4; Instars I–III: 1; Larvae: 4; Pupae: 4**

579. Weseloh, R. M.
1972. **Influence of gypsy moth egg mass dimensions and microhabitat distribution on parasitization by *Ooencyrtus kuwanai* (Howard).** Ann. Entomol. Soc. Am. 65: 64–69.

Data were collected to study the relationship of egg mass size and microhabitat to percent parasitism. Results show a higher percent parasitism on small egg masses, probably because of the accessibility of more eggs to the parasite in smaller egg masses. Difference in site-specific correlation indexes cannot easily be explained by difference in percent parasitism or by variation in egg mass sizes. Local climatic effects, topographical influences, and population characteristics of the gypsy moth are probably important. No significant correlation was found between aspect or height and percent parasitism.
**Eggs: 4**

580. Weseloh, R. M.
1973. **Relationships of natural enemy field populations to gypsy moth abundance.** Ann. Entomol. Soc. Am. 66: 853–856.

"**Field populations of** *Porthetria dispar* (L.) and its natural enemies *Apanteles melanoscelus* (Ratzeburg) (Hymenoptera: Braconidae), *Blepharipa scutellata* (Robineau-Desvoidy) (Diptera: Tachinidae), and *Colosoma sycophanta* (L.) (Coleoptera: Carabidae) were sampled during one summer and related by regression analysis. Natural enemies did not attack a greater proportion of gypsy moths at higher population densities of the latter, and so were not acting in a positive density-dependent manner at the time of the study. Also, absolute numbers of adult natural enemies were not positively correlated with gypsy moth numbers, implying that the natural enemies did not aggregate where gypsy moths were most abundant."
**Adults: 3; Larvae: 3; Pupae: 3**

581. Weseloh, R. M.
1974. **Relationships between different sampling procedures for the gypsy moth, *Porthetria dispar* (Lepidoptera: Lymantriidae) and its natural enemies.** Can. Entomol. 106: 225–231.

"A variety of field sampling procedures were used to estimate population levels of the gypsy moth, *Porthetria dispar* (L.) (Lepidoptera: Lymantriidae), and the following natural enemies: *Apanteles melanoscelus* (Ratzeburg) (Hymenoptera: Braconidae), *Blepharipa scutellata* (Robineau-Desvoidy) (Diptera: Tachinidae), [and] *Calosoma sycophanta* (L.) (Coleoptera: Carabidae). Regression analyses indicated, among other things, that gypsy moth egg-mass counts were not good indicators of tree defoliation, but that defoliation and number of gypsy moth larvae on branch terminals were correlated. Estimates of adult adundance of *A. melanoscelus* and *B. scutellata* were negatively correlated with estimates of numbers of immature parasites. Numbers of gypsy moth larvae parasitized by *A. melanoscelus* were positively correlated with numbers of *A. melanoscelus* cocoons sampled. Numbers of adult *C. sycophanta* were not correlated with larval numbers of this insect. It was concluded from these results that the procedures used to estimate numbers of natural enemy adults were not entirely adequate but may be useful for supplementing other sampling methods."
**Larvae: 3, 4**

582. Weseloh, R. M., and J. F. Anderson.
1975. **Inundative release of *Apanteles melanoscelus* against the gypsy moth.** Environ. Entomol. 4: 33–36.

"Pupae and adults of *Apanteles melanoscelus* (Ratzeburg) (Hymenoptera: Braconidae) were released in five plots in three sites in Connecticut during the summers of 1973 and 1974. Gypsy moth numbers varied from low to high in the different sites. Weekly collections of caterpillars showed consistently greater percent parasitism by

*A. melanoscelus* in the release plots than in the check plots at all three sites for at least the first 2 to 3 weeks after release. In later collections, no differences occurred in the two sites where gypsy moth numbers were low. In the site with high host numbers, percentage parasitism in the release plots was higher than in the checks, even at the seventh weekly collection after release."
**Larvae: 4, 6, 7**

583. Yadava, R. L.
1970. **Influence of temperature and humidity on the development of nuclear-polyhedrosis of *Lymantria monacha* L. and *L. dispar* L.** [in German, English summary]. Z. Angew. Entomol. 65: 167–174.

"Experiments were conducted to study the influence of six different temperature levels, viz. 8 to 12° C, 16.5 to 17.5° C, 19.5 to 20.5° C, 23.5 to 24.5° C, 26.5 to 27.5° C, and 29 to 31° C, each in combination with three relative humidities, viz. 30 to 40 percent, 70 to 80 percent, and 90 to 95 percent, on the development of . . . nuclear-polyhedrosis virus in second- and fourth-instar nun moth (*Lymantria monacha* L.) and in the second-instar gypsy moth (*L. dispar* L.) caterpillars with the help of a William's multiple temperature-incubator. The temperature clearly influences the development of nuclear-polyhedrosis virus, while the relative humidity practically fails to do so. Up to the temperature range of 26.5 to 27.5° C, [the] higher the temperature [the] faster [is] the development of [the] virus; the next higher temperature level, viz. 29 to 31° C does not seem to accelerate virus development any more. The extent of influence of temperature on the development of Fed nuclear-polyhedrosis virus in the two larval instars, viz. second and fourth, seems to be equal, although the acuteness of virus infections in the former instar is quicker than in the latter one."
**Larvae: 7**

584. Zakula, S.
1971. **The state of infection from the gypsy moth in Bosnia and Herzegovina** [in Serbo-Croatian]. Sumar. Glas. 6(1): 13–20.

585. Zanforlin, M.
1970. **The inhibition of light orientating reactions in caterpillars of Lymantriidae, *Lymantria dispar* (L.) and *Orgyia antiqua* (L.) (Lepidoptera).** Monit. Zool. Ital. (N.S.) 4: 1–19.

Larvae of *Lymantria dispar* (L.) and *Orgyia antiqua* (L.) may ". . . die of starvation while striving towards the light when inside a test tube (as observed by Loeb), but yet are able to turn away from light in their natural habitat if they reach the extremity of a leafless branch (as observed by Deegener)". A study of this problem has shown that: (1) The larva's ". . . tendency to crawl towards the light is inhibited by a specific stimulus, namely, lack of tactile stimuli in the forelegs." (2) The straight crawling tendency ". . . is suddenly inhibited by lack of tactile stimuli *in the direction of light*. (3) The reorientation turn or 'steering mechanism' is inhibited by lack of tactile stimuli *in the upwards direction* after a few repetitions of the reaction. Both conditions are present when the caterpillars are on a horizontal stick but not when inside a horizontal test tube. (4) The inhibition of the reaction to light allows the caterpillars to revert to an exploratory behavior that prevents the animal from being stuck at a dead end. This lasts for a certain period of time after which the crawling towards the light is resumed. (5) The period of time spent in exploratory behavior crawling away from light becomes longer with subsequent inhibitions of the reaction to light."
**Larvae: 1**

586. Zecević, D.
1955. **Winter feeding and development of the gypsy moth under laboratory conditions in 1952–1953** [in Serbo-Croatian, English summary]. Zast. Bilja 28: 3–20.

Results of experimental work in rearing gypsy moth in the laboratory during the winter are discussed. Egg clusters from Slovenia were used. Larvae fed on *Pyracantha coccinea* Roem., an evergreen plant. Diapause was interrupted, and larvae emerged after transfer to laboratory conditions. Length of developmental stages are given. The

question is raised whether, given favorable climatic and feeding conditions, the gypsy moth could produce two generations a year.
**Generation: 1**

587. Zečević, D.
1958. **Daily food consumption of gypsy moth caterpillars on oak trees and on *Pyracantha coccinea*** [in Serbo-Croatian, English summary]. Zast. Bilja 49/50: 23–33.

The larval and pupal stages were found to last a little shorter and longer, respectively, when the larvae were fed oak leaves rather than *Pyracantha* leaves. On an average, the larval stage lasted 42.8 days when oak-fed and 49.7 days when *Pyracantha*-fed, while the pupal stage lasted 11.1 and 10.1 days, respectively. Overall size and fertility was greater with oak feeding, yet this group showed a greater number of unfertilized eggs than *Pyracantan*-fed individuals. Average daily consumption of oak was 30.92 $mm^2$ in the first stage and 4,866.81 $mm^2$ in the sixth stage; daily consumption of *Pyracantha* was 9.66 $mm^2$ in the first stage and 2,612.04 $mm^2$ in the sixth stage. It is estimated that an egg mass of 500 eggs with complete hatching would yield enough larvae to consume about 43 $m^2$ of oak-leaf surface or 29 $m^2$ of *Pyracanta*-leaf surface. The quantity of oak corresponds to two 63-year-old trees or four 13-year- old oaks.
**Oak stands: 15, 19; Larvae: 12; Pupae: 12**

588. Zečević, D., L. Janković, and P. Sisojević.
1959. **Comparative ecological investigations of the gypsy moth in lowlands, hilly, and mountainous biotopes (annual report, 1958)** [in Serbo-Croatian, English summary]. Zast. Bilja 52/53: 162–165.

Investigations started at the end of the preceding outbreak (1949) are still underway to determine the differences in the course of fluctuations of gypsy moth populations in different biotopes. It is planned to carry out this study until it covers at least two whole gradation periods.
**Generation: 2, 12**

589. Zečević, D., and M. Janković.
1959. **A contribution to the knowledge of variability of *Lymantria dispar* in Yugoslavia: Biometrical analysis of the egg stage with geographically distant populations** [in Serbo-Croatian, English summary]. Zast. Bilja 52/53: 7–14.

Goldschmidt (1924) showed that there were different races of gypsy moths in southeastern and middle Europe. Given the geographical situation of Yugoslavia and the various climatic regimes within the country, the authors considered it likely that different races existed in Yugoslavia. They measured various parameters of the egg, comparing populations from Macedonia, Montenegro, and the island of Hvar (Mediterranean region) with those from Slovenia, Slavonia, and Serbia (continental climate) and found striking differences in the size of eggs. Using biometrical analysis, they determined that eggs in Yugoslavia differ phenotypically. In general, eggs are larger in smaller clusters. This relation is not consistent, perhaps because it changes with stage of gradation.
**Eggs: 2, 12, 13**

590. Zhalnin, Y. S.
1956. **Establishing the necessity for control of the gypsy moth in the forest Kolkhoz of Dukhovnitsi on the basis of the study of its infection with egg-eating parasites** [in Russian]. Sb. Stud. Rab. Povolzh. Lesotekh. Inst. 3: 86–88.

591. Zhikharev, I.
1928. **Injurious and other Lepidoptera in the Darnitza Experimental Forest** [in Ukrainian, Russian summary]. Mitt. Forstl. Versuchswes. Ukr. 9: 231–240.

592. Zwolfer, W.
1927. **The pebrine of the gypsy moth and the brown-tail moth, a new infection of economic importance** [in German]. Z. Angew. Entomol. 12(3): 498–500.

☆U.S. GOVERNMENT PRINTING OFFICE: 1979—603-011:64

Campbell, R. W., L. C. Levitan, E. R. Sobecki, and M. F. Tardiff.
1978. **Population Dynamics of the Gypsy Moth: An Annotated Bibliography.** Northeast. For. Exp. Stn., Broomall, Pa.
124 p. (U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-48)

This annotated bibliography contains 592 references, each dealing with some aspect of the population dynamics of the gypsy moth, *Lymantria dispar* (L.).

453--145.7 X 18.77 *Lymantria dispar* (L.) (048.1)

**Keywords:** eggs, larvae, prepupae, pupae, adults, sex ratio, fecundity, oak stands, behavior, gradation, invertebrate predators, parasites, bacteria, virus, disease, birds, mammals, environmental influence, defoliation, secondary organisms, stand dynamics, species composition, overstory structure, basal area, tree physiology, tree condition, tree mortality, *Lymantria dispar* (L.) (048.1)

Campbell, R. W., L. C. Levitan, E. R. Sobecki, and M. F. Tardiff.
1978. **Population Dynamics of the Gypsy Moth: An Annotated Bibliography.** Northeast. For. Exp. Stn., Broomall, Pa.
124 p. (U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-48)

This annotated bibliography contains 592 references, each dealing with some aspect of the population dynamics of the gypsy moth, *Lymantria dispar* (L.).

453--145.7 X 18.77 *Lymantria dispar* (L.) (048.1)

**Keywords:** eggs, larvae, prepupae, pupae, adults, sex ratio, fecundity, oak stands, behavior, gradation, invertebrate predators, parasites, bacteria, virus, disease, birds, mammals, environmental influence, defoliation, secondary organisms, stand dynamics, species composition, overstory structure, basal area, tree physiology, tree condition, tree mortality, *Lymantria dispar* (L.) (048.1)

Campbell, R. W., L. C. Levitan, E. R. Sobecki, and M. F. Tardiff.
1978. **Population Dynamics of the Gypsy Moth: An Annotated Bibliography.** Northeast. For. Exp. Stn., Broomall, Pa.
124 p. (U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-48)

This annotated bibliography contains 592 references, each dealing with some aspect of the population dynamics of the gypsy moth, *Lymantria dispar* (L.).

453--145.7 X 18.77 *Lymantria dispar* (L.) (048.1)

**Keywords:** eggs, larvae, prepupae, pupae, adults, sex ratio, fecundity, oak stands, behavior, gradation, invertebrate predators, parasites, bacteria, virus, disease, birds, mammals, environmental influence, defoliation, secondary organisms, stand dynamics, species composition, overstory structure, basal area, tree physiology, tree condition, tree mortality, *Lymantria dispar* (L.) (048.1)

Campbell, R. W., L. C. Levitan, E. R. Sobecki, and M. F. Tardiff.
1978. **Population Dynamics of the Gypsy Moth: An Annotated Bibliography.** Northeast. For. Exp. Stn., Broomall, Pa.
124 p. (U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-48)

This annotated bibliography contains 592 references, each dealing with some aspect of the population dynamics of the gypsy moth, *Lymantria dispar* (L.).

453--145.7 X 18.77 *Lymantria dispar* (L.) (048.1)

**Keywords:** eggs, larvae, prepupae, pupae, adults, sex ratio, fecundity, oak stands, behavior, gradation, invertebrate predators, parasites, bacteria, virus, disease, birds, mammals, environmental influence, defoliation, secondary organisms, stand dynamics, species composition, overstory structure, basal area, tree physiology, tree condition, tree mortality, *Lymantria dispar* (L.) (048.1)

Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories and research units are maintained at:

- Beltsville, Maryland.
- Berea, Kentucky, in cooperation with Berea College.
- Burlington, Vermont, in cooperation with the University of Vermont.
- Delaware, Ohio.
- Durham, New Hampshire, in cooperation with the University of New Hampshire.
- Hamden, Connecticut, in cooperation with Yale University.
- Kingston, Pennsylvania.
- Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
- Orono, Maine, in cooperation with the University of Maine, Orono.
- Parsons, West Virginia.
- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- University Park, Pennsylvania.
- Warren, Pennsylvania.

United States Department of Agriculture.

Northeastern Forest Experiment Station.

General Technical Report NE-49 is bound separately.

# 977-1978 report

# ortheastern orest xperiment tation

# orest service, .s.d.a.

CLEMSON UNIVERSITY LIBRARY
JUL 24 1979
SCI., TECH. & AGR. DIV.

**FOREST SERVICE GENERAL TECHNICAL REPORT NE-50**
**1979**
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
370 REED ROAD, BROOMALL, PA. 19008

## INTRODUCTION

The fourteen States in the Northeastern Forest Experiment Station's territory include a great diversity of conditions. Half of the area is covered by forests varying from remote, roadless, backcountry forests to urban forests and from spruce/fir woods of Maine to the hardwoods of the Ohio River basin. About a third of the Nation's people live here, some in big cities, some on farms, some in small towns, but all in or near the forest. These forests provide people with raw materials for industry, vital products such as paper and fine furniture, water for homes and industry, habitat for wildlife and fish, recreational opportunities, and a quality environment.

The Northeastern Station's research programs are as diverse as its territory. During 1977-78, 150 scientists in 36 teams at 15 locations had 690 research studies underway on 107 broad research problems. Many of these studies are being done in cooperation with universities in this area, and a few as far away as California. The research varies from finding better ways to grow and use hardwood trees, to improving impacts of strip mining, to understanding basic biological relationships in trees themselves and among trees in forest environments and city environments.

The highlights in this report are only a sample of the research done by the Station in 1977-78. The bibliography is a complete listing of our published research results.

We continued to work with the Association of State College and University Research Organizations (ASCUFRO) on long-range planning. With ASCUFRO we held work conferences of scientists and with representatives of forest users, the general public, to identify forestry research needs and priorities. The results of this planning effort were published in 1978 in "Program of Research for Forests and Associated Rangelands - Northeastern Region," USDA-Forest Service General Technical Report NE-42. Similar planning was done in the Southern, Western, and North Central Regions of the country. The national perspective has been compiled in "National Program of Research for Forests and Associated Rangelands," USDA-Forest Service.

We have been working closely with the Northeastern Area, State and Private Forestry, to strengthen timeliness

and effectiveness of efforts to get research results applied. Examples include work on hardwood mill improvement, the loblolly X pitch pine hybrid, gypsy moth management, and the weak link approach to logging analysis.

The work to find effective ways of protecting American elm trees from Dutch Elm Disease continued and is yielding significant results. The special accelerated program on the gypsy moth, as part of a USDA team effort, has been phased down as scheduled. A compendium of research findings is being prepared for publication. We are continuing important work on the gypsy moth where leads are promising or gaps in knowledge are critical.

As the accelerated Gypsy Moth Program winds down, we have mobilized a special accelerated program of research on the spruce budworm problem. This insect has been very destructive over vast acreages in Canada for many years and is affecting parts of northeast and northcentral states. The research program is designed to take a comprehensive and long-range view of the problem and seek an integrated pest management approach that will be environmentally acceptable as well as effective in protecting the forest. Our spruce budworms program is coordinated with a similar effort in the far West and is part of a Canadian-U.S. scientific partnership.

The Northeastern Station has been doing research on strip mining for many years. The aim is to help design mining operations to minimize damage to soil and water and to have economical and effective ways of restoring the land to a productive condition. Demands for new and better technology is higher now than ever before, and we have increased the size of this program.

We have established a new project on urban forestry on the campus of the College of Environmental Science and Forestry at Syracuse, New York. Combining the scientific expertise in forestry, geography, and urban planning, and working cooperatively with the College and other universities, the project is seeking ways to incorporate urban forestry into overall urban planning. Related research continues in cooperation with the nine-university Consortium for Environmental Forestry Studies and at our projects at Amherst, Massachusetts and State College, Pennsylvania. The Pennington, N.J., project moved to the Pennsylvania State University campus in September 1978.

We are continuing to search for better ways of harvesting hardwood timber on rough Appalachian terrain while minimizing environmental impacts and have developed some promising leads.

Forest Recreation Research at this Station has nationwide significance. Building on earlier success in analyzing demand and markets for camping, scientists have studied the national outlook for skiing. Another team is contributing to our knowledge of ways of managing recreation in backcountry and their new waste composter is being pilot tested in the Cascade mountains of Washington as well as the White Mountains of New Hampshire.

Our Renewable Resources Evaluation project continued to maintain their excellent record of keeping up with the 10 year cycle of forest surveys of the 14 states and also expanded its work to collect and analyze more data about a variety of forest resources in addition to timber.

The energy crisis is real in the Northeast, and many people are turning back to wood for home heat. Forest industries are using wood waste for all or part of their needs. A few pioneering institutions, such as hospitals, have converted to wood from fossil fuel. There is also an interest in the potential for forests to fuel electric power generating plants. We have redirected some of our scientific manpower to study these important areas and are working closely with other agencies with related missions.

Many years of work have led to development of a loblolly X pitch pine hybrid that shows great promise for combining the form and growth of the loblolly pine with the hardiness and fire resistance of pitch pine. These trees are being field tested in cooperation with several states and industry.

Our old friends will notice that our mailing address has changed from Upper Darby to Broomall, Pa. Early in 1978 Station headquarters offices were moved a few miles to a more suitable office building.

# RESEARCH HIGHLIGHTS

## DUTCH ELM DISEASE

Not long ago, Dutch elm disease (DED), a major disease of both urban and forest trees, was uncontrollable. There were heavy losses of timber and urban trees. Researchers have developed strategies that will help control DED including injecting trees, using pheromonal or host attractant chemicals, and removal of infected trees.

## INTENSIFIED SANITATION CONTROL

Studies have confirmed the possibility of reducing the incidence of DED by increasing the speed with which diseased trees are identified and removed. A cost analysis was developed that showed this sanitation program to be more economical than usually practiced ones.

These new results were obtained by increasing the number of disease surveys from one to three during the summer. Affected trees were removed within twenty working days after detection of the disease, instead of waiting to remove them during the fall and winter months. This intensified effort reduced the incidence of DED by 1.2 percent the first year, 2.4 percent the second year, and 6.7 percent the third year (1977).

The cost of intensified sanitation was evaluated and results showed that over three years, there was a dollar savings of approximately twenty-five percent and a saving of an additional ninety-two trees per thousand in the elm population.

## GRAFT INOCULATIONS FOR DED

Dutch elm disease (DED) and phloem necrosis are the two most serious diseases of elms in the United States. Certain American elm selections and European and Asiatic species and hybrids have shown resistance to DED, but none have been adequately tested for resistance to elm phloem necrosis. After repeated graft inoculations of some of

those with phloem necrosis, we have found that urban elm (*Ulmus pumila* x *U. Hollandica*), *Ulmus Wilsoniana*, and *U. pumila*, have exhibited no susceptibility. On the other hand, a promising DED resistant American elm selection clone 368 x R182 was found to be susceptible in 1978 following inoculation in 1977.

This information is important to tree breeders, foresters, arborists, and pathologists interested in developing and providing disease resistant trees to the general public.

## SPRUCE BUDWORM

Spruce budworms have infested approximately 150 million acres in Eastern North America and approximately 10 million acres in Western North America. To combat this outbreak, the Canada-U.S. Spruce Budworms Program was organized in August 1977 with the Northeastern Forest Experiment Station as lead station for the eastern component.

### TRAINING GUIDE FOR POPULATION STUDIES

Survey entomologists and pest managers routinely sample branches from host trees and bring them for examination to the laboratory for Spruce Budworm population studies. A training guide has been produced to aid egg mass examiners in the basic steps needed to examine foliage, including "do's" and "don'ts," safety precautions, equipment needs, and other helpful hints.

### TREATMENT

Studies conducted in Maine of stands unprotected and protected by aerially applied chemicals have shown there are substantial differences in the mortality of unprotected mixed wood versus softwood stands. The studies have shown that spruce mortality is slight. Suggested treatment is based on economic values gained from protection by applying differential protection strategies on a stand-by-stand basis.

Because of the variation in response of spruce in the red/black spruce hybrid array, studies suggest that a best tree for propagation and planting relative to budworm attack can be selected.

## GYPSY MOTH

The northeastern forest has a variety of woodland related values that varies dramatically when insects change in number and/or behavior. The gypsy moth threatens high priority recreational areas, urban property, and timber resources in this forest region.

## GYPSY MOTH PEST MANAGEMENT DECISION SYSTEM

A prototype management decision system has been developed to suppress, control, and contain the gypsy moth. This management prototype represents the first large-scale decision-making system for pest managers over a multi-state region to control a forest urban insect. The decision to use a particular type of system will depend on the objective chosen--eradication, containment, and/or suppression. Methods for implementation will be included and a monitoring feedback system will be a vital part of this program.

## SAMPLING METHODS FOR PEST MANAGERS

Pest managers need efficient sampling methods to gauge insect numbers and decision-making techniques to aid in determining a feasible course of action. These methods must be efficient and reliable. Pest management personnel now have a statistically sound method for enumerating gypsy moth egg mass densities in forested areas. This method utilizes a small, fixed circular ground plot for observing egg masses on undergrowth, down trees, and litter. In addition, a variable radius prism plot is used to select live trees for observing egg masses. The details of the fixed- and variable-radius plots (FVP) sampling method for gypsy moth egg masses are described in a new USDA handbook.

## SURFACE MINING

Research at the Station has aimed at reducing damage to the environment and forest resources due to strip mine operations and restoring already mined land to produce water, timber, wildlife, range, recreation, and other benefits.

## SURFACE MINE SPOILS MEASUREMENT

Research results indicate that conventional soil mechanics tests are reliable for describing shear strength and permeability of mine spoils. Shear strength of a mine spoil is related to its dry density, moisture content, and plasticity index. Spoil properties dictate how the spoil mass will behave after mining and reclamation, and provide an indication of the revegetation potential. Physical, chemical, and mineralogical properties are all important. These findings are useful to researchers, government agencies, and the coal industry in developing mining and reclamation plans and regulations.

## REVEGETATION

Vegetation of steep slopes and toxic spoils often requires the application of soil amendments, planting of acid-tolerant species, and the introduction of beneficial microorganisms.

Researchers found that vegetation can be established at an increased rate, including a doubled herbage yield, with the combined use of lime, fertilizer, and mulch. Mulches on steep slopes and dark-colored toxic spoils aided establishment of seeded species by reducing surface erosion and lowering soil temperatures. Tree leaves mixed into the mine spoils provided benefits similar to bark and hay mulches.

After ten years, trees planted with a legume cover are now taller than trees planted with grass or no herbaceous cover. Pine and hardwoods interplanted with black alder are now larger than trees planted without alder.

## MULCHING FOR SURVIVAL OF HARDWOODS ON MINE SPOILS

Hay, bark, and straw mulches generally help promote the establishment of vegetation on strip mined land while wood chips and hydromulch generally are of little value. Regulatory agencies in several states now approve the use of shredded hardwood bark as mulch. Preliminary results indicate that composite municipal waste also may be valuable in mined land rehabilitation. Chemical soil stabilizers alone or in combination with mulching materials provide effective treatments for erosion control.

Data from Kentucky indicate that mulching with wood bark increases survival of some hardwoods planted on mine spoils.

## WILDLIFE HABITAT HANDBOOK FOR LAND OWNERS AND MINE OPERATORS

A "Guide for Vegetating Surface-Mined Lands for Wildlife in Eastern Kentucky and West Virginia" has been prepared to help operators plan for wildlife in the rehabilitation of their mined land.

The guide lists plants suitable for revegetating surface mine sites, and identifies species tolerances to environmental factors common to surface mines. It discusses planting techniques, lists recommended seeding mixtures, and illustrates planting patterns beneficial to wildlife as well as providing information on sources of planting stock.

# HARDWOOD TIMBER HARVESTING

## CABLE LOGGING IN EASTERN FORESTS

It has been demonstrated that skyline systems can reduce the environmental impacts of timber harvest, but it remains to be proven that skyline systems are an economically viable alternative to existing skidding systems in

the East. Two years of experience on the Fernow Experimental Forest and observation of other cable systems provide insight on systems suitable for timber harvest in the Appalachians.

A running skyline--one that can be raised or lowered at will--with a swinging boom seems best for mountain hardwoods. Skyline spans and equipment should have the capability to yard 1,000 feet or more, but a 400 to 600 foot range will be used most often. The system should be light and mobile to operate on steep and narrow roads.

The region's timber values probably cannot support machines costing more than $100,000. Given these insights, it may be possible to adapt the sophisticated cable systems now used in the West to eastern timber and topography conditions.

## BUILDING A PROTOTYPE CABLE YARDER

A patent has been applied for a cable yarder that was built as a prototype by researchers. This yarder can be utilized in thinning cuts and pulpwood operations where winch line pull does not exceed 6,000 pounds. Researchers think the yarder will create a one-piece equipment logging operation where the logger will be able to build roads, skid, and load timber with one machine.

## WEAK LINK LOGGING SYSTEMS ANALYZER

A Weak Link Logging Systems Analyzer was developed to help loggers obtain information about logging operations. Loggers can use this analyzer to estimate the productivity of each component in their system, locate bottlenecks, and estimate logging costs. The Systems Analyzer is accomplished through nomograms that enable loggers to evaluate a wide variety of machine combinations and operating conditions.

The application of Weak Link is being promoted through workshops for loggers and service foresters. These workshops explain how the system is applied and how it can be adapted to variations in logging conditions.

## FOREST RECREATION

### CAMPING IMAGES

A nationwide sample survey of households asked if camping was interesting, friendly, refreshing, inexpensive, easy, fun, convenient, clean, safe, uncrowded, pleasant, or comfortable. Images of camping's attraction and environment were compared for several different population groups, including potential campers, active campers, and inactive campers.

It was found that camping's appeal was strongest among heads of households under thirty years of age. Unfavorable images--expensive, dirty, crowded, and inconvenient--were seen as barriers to potential campers. Unless problems resulting from camping's popularity are recognized and resolved, images of camping may further deteriorate.

### NATIONAL CAMPING INDICATORS PROGRAM

Representing a public-private cooperation jointly developed and sponsored by NCOA, the campground publishing industry, the Northeastern Forest Experiment Station, and the University of Vermont, this project sponsored the development of two nationwide indicators of camping activity.

The National Campground Occupancy Index served as a barometer of camping activity at more than 10,000 commercial campgrounds and was based on weekly occupancy reports provided by cooperating private campgrounds. Data was matched by computer with previously reported figures on capacity, types of facilities, years in business, and fees to provide a sound basis for comparisons and trend measurement.

The National Camper Satisfaction Index monitored the quality of camping experiences provided at these campgrounds and was developed from a simple report card evaluation of experiences provided by the campers. Cooperating campgrounds received a computer printout comparing the reaction of campers at their campgrounds with those of others in the sample.

## NATIONAL SKIER MARKET SURVEY

This comprehensive examination of a major outdoor recreation market was conducted cooperatively by the Northeastern Forest Experiment Station, USDA Forest Service, and Cornell University. A survey of potential, active, and inactive skiers provided data of detailed descriptions of public images of and attitudes towards skiing, its costs, attractions, facilities, and market needs as well as sizes of various skier markets. For the first time, public and private planners and developers of skiing facilities have an objective estimate of the skier market's potential for short-term growth, both regionally and nationally. An assessment of the adequacy of existing developed ski areas was also provided.

In terms of development costs, operational costs, and investment risks, skiing is probably one of outdoor recreation's best consumer bargains and could be more effectively promoted. Skiing's highly popular appeal to all age groups should be developed through local efforts and on-the-ground contact rather than industry-wide promotional campaigns.

## WASTE COMPOSTING METHODS

Because of health hazards, disposal of human waste has been one of the most critical problems for backcountry managers. In the 1930s, only one or two visitors per night used backcountry facilities, but today these same areas average ten to twenty visitors per night.

A short-term solution to this problem has been the relocation of privies. With the requirement that soil beneath a privy must be at least four to five feet deep, this solution is limited by the number of possible privy sites.

Researchers have developed a simple bin composter to compost privy wastes mixed with ground bark in a closed container. The decomposition process takes about two weeks and the end product is a humuslike substance, free of pathogens and odor. The compost bin can be maintained easily by regular field crews and the cost per unit is $100.

## SUGAR MAPLE

### REDUCE FUEL COSTS FOR SYRUP PRODUCERS

Our researchers studied the engineering and economic effects of heat exchangers using steam that would have been lost in the evaporation process to preheat incoming sap. This study found that efficiency was increased by 15 to 17 percent with heat exchangers. Syrup produced in evaporators with heat exchangers was similar in flavor and composition to syrup produced in conventional systems, and heat exchangers can reduce production costs. The study also found that use of heat exchangers will give the sugarhouse a supply of hot water and yield greater production and higher profits.

### DISCOLORATION AND DECAY IN TAPPED SUGAR MAPLE

Studies in Maine, Michigan, New York, Pennsylvania, and Vermont indicate that repeated use of paraformaldehyde within tapholes leads to rapid development of decay in sugar maple trees.

### VAPOR COMPRESSION DISTILLER OR OPEN-PAN EVAPORATORS

Although mechanical compression distillation had been used for desalinization since World War II, its potential for processing maple sap had not been investigated. Researchers tested vapor compression distillers for processing maple syrup and found that vapor compression equipment evaporated one pound of water with .047 pounds of steam equivalent (electrical energy); open-pan evaporators of similar capacity required 1.5 pounds of steam equivalent (oil energy) to produce one pound of water; vapor compression evaporation produced syrup of equal quality to that from conventional open-pan evaporation; and a central plant producing 8,000 gallons of syrup per year should yield a return of sixteen percent on investment. Increasing annual syrup output should increase the return on investment. Vapor compression distillers provide an alternative to the energy intensive conventional open-pan evaporation system for the large centralized syrup-processing plant.

## URBAN FORESTRY

### URBAN FOREST VALUES

With the current rapid increase in land values near urban areas, there is a decrease in forest investments. Timber management is a declining factor in real estate transactions

Research shows that urban people attach high property values to trees around homes. These studies also show that real estate developers can preserve trees around homes at a low cost relative to their value, but many developers lack the technical knowledge to preserve trees in a healthy condition.

There is a need and opportunity for service, extension, and consulting foresters to help developers preserve trees around homes. This kind of cooperation will produce both economic and environmental benefits.

### SQUIRREL HABITAT IN URBAN AREAS

Gray squirrels provide pleasant opportunities for some city residents to interact with something wild. In Springfield, Massachusetts, squirrel activity was recorded during a three-year study of seventy-five plots in five habitat areas.

Highly urbanized areas with tree-lined streets had low squirrel numbers as compared to rural habitats. In forested city areas, squirrel abundance was estimated to be about two squirrels per acre, the same as for rural forests. Parks, college campuses, and cemeteries created a habitat that resulted in more squirrels than were found in rural forests.

## FOREST MANAGEMENT

### SELECTION SILVICULTURE

Potential users of selection silviculture in spruce/fir stands can now compare early results from this system

with unregulated harvesting (commercial clearcutting) and no management for wood products (woodland preserve or wilderness).

Twenty years of records indicate that spruce/fir stands will respond to the selection system of silviculture. Records also show that stand quality in the selection system is improved, species composition can be altered, diameter-class distribution approaches a stated goal, stand density is controlled, and yields are increased.

The lack of direct comparisons between selection silvicultural management and no management in spruce/fir has been partly responsible for the limited acceptance of the method in the past.

## EARLY RELEASE OF HARDWOODS

Based on a five-year study, Appalachian hardwood forest managers should not plan to select and release yellow-poplar, red oak, black cherry, or sugar maple crop trees at a very young age. In most instances the released crop trees do not grow any better than the nonreleased crop trees. Knowing this, public and private land managers are now investing their money in other cultural practices.

## PLANTING SITES FOR BLACK WALNUT

Thirteen years after black walnut and northern red oak were planted on a clearcut oak site, researchers found that black walnut seedlings could be established and grown if planted on the best sites and with control of competing competition. Planted stock cannot compete successfully with other fast growing trees, shrubs, and sprouts with established root systems.

Northern red oak seedlings failed to develop satisfactorily regardless of treatments or the site quality.

Proper selection of planting site and adequate control of competing vegetation are extremely important if foresters are to be successful with black walnut on recently clearcut upland oak sites.

## IDENTIFYING TREE QUALITY AT AN EARLY AGE

Some important factors that determine the value of standing timber are species, size, and stem quality. In young precommercial size stands, there is no standard or system for evaluating individual trees for their potential to produce high quality hardwood products. Recently, scientists developed a system to classify trees into quality classes based on tree and stem characteristics. This system is independent of product specifications and is designed to identify tree quality at an early age. This procedure will enable the forest manager to apply cultural treatments, such as thinning and pruning, that will increase the number of high quality trees and the harvest value.

## TOXIC CHEMICALS FROM HERBACEOUS PLANTS PREVENT BLACK CHERRY REGENERATION

Low density cherry/maple orchard stands and treeless plains on the Allegheny Plateau in northwestern Pennsylvania developed following turn-of-the-century cuttings, fires, and deer browsing. With a ground cover of fern, grass, goldenrod, and aster, these areas failed to regenerate because biochemicals toxic to cherry and other hardwoods were released from the foliage and roots of these herbaceous plants.

Following shelterwood cutting of Allegheny hardwood stands on poorly drained sites, woodland species of ferns and grass spread rapidly, dominating the site within several years. Toxic biochemicals from these species also interfered with growth of black cherry and other hardwoods during stand regeneration.

Through studies in progress, forest land managers can now better predict success or failure of regeneration prescriptions based upon the amount of herbaceous vegetation present before or at the time of cutting.

Basic biological knowledge about the release and fate of toxic biochemicals (the phenomenon of allelopathy) are helping to bring a new understanding of the forest regeneration process.

## STOCKING GUIDES FOR ALLEGHENY HARDWOODS

Control of stand density is the principal means foresters use for regulating stand growth. Through the years many stocking guides have been developed to aid in judging how well a stand is stocked compared to a prescribed standard.

A new stocking guide has been developed for stands of Allegheny hardwoods that contain mixtures of black cherry, red maple, sugar maple, beech, white ash, birch, and other species. This guide incorporates, for the first time, a measure of species composition necessary because of the widely different growing space requirements. This guide permits accurate evaluation of Allegheny hardwood stocking, and provides a sound basis for determining minimal residual densities to leave after thinning or selection cuttings.

## RELATION OF SPECIES TO HABITAT

Eleven different forest habitats were studied and defined for areas of granitic drift in the White Mountains of New Hampshire. Species varied with different soil materials. Successional beech/sugar maple/yellow birch stands characterize the fine till soils and the enriched, or cove sites, where White ash also is common. Beech, birch, and red maple predominate in stands on washed fine till and coarse till soils. Red maple is the most abundant species on sandy sediments, silty sediments, and dry compact till soil. Softwoods, especially red spruce and eastern hemlock, characterize habitats having poor drainage, shallow soils, outwash, or wet compact till.

A previous study in old stands indicates that pure hardwood stands occur only on coarse till, fine till, and enriched sites. On most of the other habitats, the hardwood cover tends to change gradually to softwoods. Site index generally averages highest on strong hardwood habitats and the lowest on strong softwood habitats, although the site index of red maple remains comparatively high even on strong softwood sites. Habitat classification should be used in conjunction with gradient analysis to analyze or depict the relationships of forest vegetation to environmental conditions.

## AIR POLLUTION

### NEEDLE MOTTLE IN EASTERN WHITE PINE SEEDLINGS: A SELECTION PROCESS FOR AIR POLLUTION TOLERANCE

Studies show positive correlations between morphological characteristics in eastern white pine (*Pinus strobus L.*) and seedling sensitivity to air pollution. Of eleven plant variables, needle mottling of two-year-old white pines was an indicator of susceptibility to air pollution. This foliar characteristic allows for detection and removal of genetically susceptible seedlings in the nursery during grading. Stability of pollution response during various ontogenetic stages will aid in selection of tolerant seed sources and seedlings of white pine.

### EFFECTS OF AIRBORNE CONTAMINANTS ON EASTERN FORESTS

The Hubbard Brook Experimental Forest in New Hampshire is an international focal point for ecosystem research and a place where airborne pollutants come to rest. Gases and particles from the combustion of fossil fuels in areas to the west cause formation of acidic pollutants that tend to fall out of the air over the Northeast. Sulphur is a particular culprit, and tests at Hubbard Brook have shown that sulphur content of the air and the prevalence of acidic precipitation, "acid rain," are closely correlated. Unfortunately the highest levels of this fallout occur during the summer months when its potential to adversely affect plant growth is greatest.

## WATERSHED MANAGEMENT

### EFFECTS ON STREAMFLOW FROM USE AND LOCATION OF LOGGING ROADS

Watershed 2 on the Fernow Experimental Forest has been logged four times since the turn of the century. The scant

evidence available suggests no major effects on stream flow after high grading the old growth hardwood in 1905 or after harvesting blight-killed chestnut during World War II. The effects of diameter-limit harvest in 1958 and 1972 are well documented. Both cuts caused small increases in stream flow that lasted for no more than two years. Water quality was unaffected except for temporarily increased turbidity caused by improper use and location of logging roads. The evidence suggests that continued diameter-limit harvest will not harm forest streams if responsible road practices are followed.

### USE OF FOREST LAND FOR DISPOSAL OF SEWAGE SLUDGE

Forests may be used as an intentional dump for wastes such as sewage sludge. Dewatered sewage sludge was applied at rates of 25 to 125 metric tons/hectare (t/ha) to the forest floor at Hubbard Brook. The light application of sludge had little effect on soil water chemistry, but the 125 t/ha treatment tripled concentrations of some nutrients for up to one year. Based on knowledge of the Hubbard Brook Ecosystem, it was concluded that an intermediate rate of 75 t/ha could be applied without releasing nutrients to streams or affecting ecosystem function.

## INSECTS AND DISEASES

### DECAY RESISTANT TREES

Results of recent research indicate that it is now possible to make selections within a species for decay resistance. Decay resistance here is defined as resistance to spread, rather than resistance to infection. Using the CODIT model for compartmentalization of decay in living trees, it is possible to select trees within a species that wall-off or compartmentalize defects to very small volumes. It appears that this intrinsic capacity for effectively compartmentalizing is under genetic control. This means we can now select trees that can be wounded repeatedly but will still respond so effectively that even when defect columns develop, they will be very small. We see this as a major breakthrough in the field of forestry.

## OAK BORER CONTROL KEEPS WORKING

Silvicultural control of the red oak borer produced an immediate reduction of 66 percent damage on test plots in southern Ohio. Borer damage has continued to decline and four years after treatment, the damage to stands is ten percent of the pretreatment level. Untreated stands show a twenty percent increase over the same time span. This research makes possible a dramatic reduction of oak timber quality loss, estimated at over $100 million annually throughout 140 million acres of eastern oak forests.

# FOREST BIOLOGY

## FUTURE GROWTH POTENTIAL OF TREE SEEDLINGS

Analysis of the growth of Picea abies seedlings suggests the possibility of predicting the future growth potential of tree seedlings on the basis of early growth features.

In tree seedlings, all new leaves and stem segments have their beginnings in the mass of growing and dividing cells at the stem--the apical meristem. Though the cells in this dome-shaped region typically produce about twenty-five percent of their own volume of new growth per day, the volume of this small dome itself increases very slowly.

Methods have been developed to calculate the absolute and relative growth rates of apical meristems of conifer seedlings. Researchers have found that the relative growth rate varies little with seedling age whereas the absolute growth is largely determined by the apical dome volume. That volume, in turn, is determined by how much new growth is reinvested in the dome itself increasing the capital volume. The investment ratio can be as high as thirty percent, but it can be as low as zero, or even negative.

There are good reasons for believing that in their future growth young seedlings with high investment ratios

will outperform those with low ratios. Further research is needed to learn how the investment ratio may be controlled.

### MYCORRHIZAE

Studies on the biochemical-physiological effects of growth substances in ectomycorrhizae of Pinus virginiana, have shown that only a few species of fungi tested have metabolic activity and that hormones are not consistently produced. Various amounts of synthetic hormones and indoleacetic acid may produce changes similar to those in natural ectomycorrhizal associations. The presence of the fungi consistently reduced the rate of metabolism of soybean callus tissue and fungal metabolic products may be a key to increased long life of mycorrhizal roots.

## FOREST ECONOMICS

### AUTOMATED MANAGEMENT PLANNING SYSTEM (AMPS) FOR THE SMALL-FOREST LAND OWNER

AMPS is designed with two people in mind: the practicing forester and the small-forest land owner. It relieves the forester of computational drudgery and offers more time for exercising professional skills. It allows the owner to incorporate wants and needs into the management planning process for the small-forest.

AMPS, a flexible package of optional subsystems, provides summaries of forest inventory data, estimates of forest values, a series of cutting strategy simulators, an economic analysis, growth projections, and a listing of possible markets. The user may select, as output, various combinations to tailor a management plan to both individual woodlots and individual owners.

AMPS is being field tested by the Indiana Department of Natural Resources. It is also an integral part of FACTS: Fast Agriculture Communications Network System, a statewide network of computer terminals that will soon link the Purdue University Agricultural Experiment Station with each county extension office in Indiana.

## FOREST LAND USE DECISIONS

The ability to gauge the capacity of forest resource to satisfy future timber requirements is needed to solve problems arising from competition for use of forest land. Potential timber production under management alternatives has been weighed against estimates of timber requirements for the year 2000. By depicting the capabilities filling timber requirements in different parts of the region, these analyses indicate areas that will be affected by further shifts toward nontimber use of forest land.

One option combines forest management at the present level with emphasis on harvesting the best timber-growing sites first. Under this type of forest management, projected timber requirements for the year 2000 could be met from roughly half the region's commercial forest area. By allowing flexibility in forest land use decisions, the forest could accommodate both intensive management and multiple use objectives.

# UTILIZATION

## HARDWOOD LOGGING RESIDUES

Researchers determined the need for more information on the yields of useable products that could be recovered from residue hardwood. A study was made to find the potential yields for different levels of harvesting intensity on a clear-cut cove hardwood sawtimber stand in western Virginia. This information will aid in finding economical ways to recover and use residues that will help increase the nation's wood supply (without cutting additional timber), while reducing the environmental impact of logging and the cost of forest regeneration.

## NEW USE FOR LOW GRADE HARDWOODS

Furniture manufacturers have considered number 2 Common and lower grades of lumber undesirable because the

lower grades of lumber do not yield the longer length cuttings desired by the furniture industry.

In an attempt to increase the use of lower grades of fine hardwood lumber, researchers have developed a new method of end joining pieces of wood. This end joining process is called Serpentine End Matching (Sem). The glue line of this joint is described as a sine wave that resembles the grain pattern of flat sawn wood and allows the joint to be camouflaged.

Furniture industries have shown a great deal of interest in this new process that will allow them to use the lower grades of hardwood lumber that have been considered undesirable.

## HARDWOOD BARK HELPS HEAL SCARRED LANDSCAPES

Shredded hardwood bark makes a high quality mulch for controlling erosion and establishing vegetation on disturbed soils. Because shredded bark resists movement by heavy rains and winds and needs no asphalt to hold it in place, bark is particularly suitable for mulching grass-legume seedings on highway roadsides and surface mined areas. These applications are high volume uses for hardwood bark and are resulting in new markets for bark residues generated at log processing plants. A bark mulch plant has been established in south central West Virginia and provides a market for a previous waste material from numerous area sawmills.

Guidelines for preparing mulch specifications and shredded hardwood bark have been prepared and broad scope plan for application is being implemented. Specialized equipment for transporting and applying bark mulches and wood residues has been evaluated for performance and costs.

## STATION BIBLIOGRAPHY

The Station Bibliography contains all publications actually published during 1977 and 1978 by the Northeastern Forest Experiment Station. Publications are classified in the six major research areas:

### A. FOREST ENVIRONMENT RESEARCH

#### 1. Watershed Management Research

3, 81, 82, 83, 84, 90, 91, 92, 93, 94, 106, 133, 144, 145, 146, 212, 232, 236, 237, 238, 239, 244, 259, 276, 277, 281, 310, 311, 312, 313, 314, 320, 321, 322, 323, 333, 353, 373, 377, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 405, 410, 413, 414, 415, 416, 417, 429, 445, 520, 521, 530, 542, 544, 555.

#### 2. Wildlife Habitat Research

86, 87, 96, 109, 115, 223, 295, 297, 324, 407, 422, 508, 509, 510, 537, 579.

#### 4. Fisheries Habitat Research

74

#### 5. Forest Recreation Research

25, 31, 78, 83, 119, 134, 139, 140, 142, 143, 184, 185, 186, 187, 188, 227, 290, 291, 292, 293, 294, 304, 305, 306, 307, 315, 319, 326, 327, 334, 361, 362, 367, 372, 385, 407, 419, 506, 522, 556, 557, 558, 559, 560.

#### 6. Urban Forestry

8, 12, 24, 25, 36, 38, 53, 54, 55, 70, 71, 72, 78, 80, 110, 111, 112, 113, 114, 116, 117, 118, 136, 140, 141, 179, 190, 219, 224, 225, 229, 230, 231, 258, 271, 278, 319, 325, 332, 339, 349, 354, 358, 359, 360, 361, 365, 366, 368, 369, 373, 375, 377, 381, 383, 385, 389, 406, 418, 426, 431, 441, 464, 465, 497, 498, 506, 512, 513, 521, 523, 529, 541, 551, 552, 553, 564, 582, 589.

## B. FOREST INSECT AND DISEASE RESEARCH

### 1. Forest Insect Research

4, 13, 15, 16, 17, 34, 58, 60, 61, 62, 63, 64, 65, 66, 68, 97, 98, 108, 120, 121, 127, 128, 130, 159, 160, 161, 181, 182, 189, 192, 219, 220, 221, 246, 248, 249, 250, 251, 252, 253, 263, 264, 288, 289, 295, 296, 297, 308, 309, 330, 331, 343, 344, 363, 364, 370, 374, 378, 388, 412, 420, 421, 430, 433, 527, 528, 531, 533, 534, 535, 536, 538, 549, 570, 583, 588.

### 2. Forest Disease Research

5, 14, 26, 27, 28, 29, 30, 39, 40, 56, 59, 67, 85, 122, 123, 124, 125, 126, 147, 150, 175, 180, 183, 199, 200, 222, 245, 246, 247, 265, 266, 267, 268, 282, 328, 355, 371, 376, 389, 391, 392, 404, 423, 424, 432, 433, 434, 439, 452, 457, 458, 466, 467, 468, 469, 470, 471, 472, 473, 474, 476, 477, 478, 479, 480, 481, 482, 483, 484, 485, 486, 487, 488, 489, 490, 491, 492, 493, 494, 495, 496, 498, 512, 568, 571, 572, 573, 574.

## C. FOREST FIRE AND ATMOSPHERIC SCIENCES RESEARCH

### 4. Ecological Relationships

316

### 5. Weather Modification and Weather Effects

8, 38, 53, 55, 95, 124, 126, 141, 224, 226, 258, 271, 330, 332, 339, 352, 389, 426, 458, 459, 497, 512, 513, 529, 553, 589.

## D. TIMBER MANAGEMENT RESEARCH

### 1. Biological Relationships

11, 37, 41, 61, 75, 99, 102, 106, 122, 126, 129, 153, 193, 195, 202, 203, 205, 206, 207, 208, 209, 210, 235, 240, 241, 242, 243, 244, 248, 254, 255, 256, 257, 260, 269, 270, 272, 279, 280, 283, 284, 300, 312, 333, 336, 337, 342, 346, 350, 351, 369, 390, 411, 427, 428, 433, 442, 443, 444, 445, 458, 507, 511, 532, 548, 550, 566, 570, 577, 584.

2. Silviculture

99, 100, 101, 103, 104, 148, 149, 150, 154, 155, 162, 194, 201, 204, 233, 237, 255, 261, 262, 285, 286, 287, 299, 300, 302, 303, 323, 335, 384, 440, 447, 448, 499, 500, 501, 502, 504, 505, 514, 515, 516, 517, 518, 519, 520, 542, 554, 577.

3. Management and Mensuration

9, 10, 75, 77, 86, 107, 234, 298, 301, 345, 387, 440, 446, 454, 456, 526, 578, 590.

4. Genetics and Tree Improvement

105, 157, 172, 173, 174, 175, 179, 201, 211, 317, 318, 335, 338, 451, 455, 483, 484, 576, 580, 581.

5. Special Products

69, 156, 158, 403, 567, 568, 569.

E. FOREST ECONOMICS AND MARKETING RESEARCH

1. Forest Resource Evaluation

1, 2, 18, 19, 20, 21, 22, 23, 35, 42, 43, 45, 46, 47, 48, 49, 50, 51, 52, 138, 167, 191, 273, 274, 275, 340, 341, 408, 409, 425, 450, 543, 548.

2. Forest Economics Research

44, 67, 107, 135, 162, 163, 165, 166, 168, 171, 196, 197, 198, 216, 217, 228, 329, 345, 347, 356, 357, 380, 407, 453, 454, 460, 524, 525, 526, 545. 546, 547, 585, 586, 587.

3. Forest Products Marketing Research

57, 131, 132, 137, 164, 169, 170, 215, 218, 292, 294, 348, 379, 461, 462, 463, 539, 540, 565, 566.

## F. FOREST PRODUCTS AND ENGINEERING RESEARCH

### 1. Forest Engineering Research

32, 33, 95, 151, 152, 276, 397, 503, 578.

### 2. Forest Products Utilization Research

6, 7, 73, 79, 88, 89, 176, 177, 213, 214, 218, 435, 436, 437, 438, 449, 539, 540, 562, 563, 575.

1. Adams, Edward L., and Daniel E. Dunmire.
1977. SOLVE II: A technique to improve efficiency and solve problems in hardwood sawmills. U.S. Dep. Agric. For. Serv. Res. Pap. NE-382. 19 p.

A general description of a computerized technique for analyzing hardwood sawmills. Included are discussions of the input data, the resulting analytical information, and examples of how this information can be used by a mill manager. The technique gives the manager an economic and noneconomic analysis of his sawmill's operation.

2. Adams, Edward L., and Daniel E. Dunmire.
1978. SOLVE II USERS MANUAL: A procedural guide for a sawmill analysis. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-44. 18 p., illus.

A procedural guide for using the SOLVE II computerized technique to analyze hardwood sawmills. Included are discussions of: (1) analysis design, (2) data collection, and (3) computer card preparation and use. By following this guide, sawmill analysts should have little difficulty in using the technique.

3. Allaire, Pierre N.
1978. Reclaimed surface mines: new potential for some North American birds. Am. Birds 32(1): 3-5.

4. Anderson, J., M.A. Hoy, and R.M. Weseloh.
1977. Field cage assessment of the potential for establishment of Rogas indiscretus against the gypsy moth. Environ. Entomol. 6: 375-380.

5. Anderson, Robert L., and Leon S. Dochinger.
1978. How to identify white pine susceptible to air pollution. U.S. Dep. Agric., Northeast. Area, State and Priv. For. 4 p.

6. Araman, Philip A.
1977. Use of computer simulation in designing and evaluating a proposed rough mill for furniture interior parts. U.S. Dep. Agric. For. Serv. Res. Pap. NE-361. 9 p., illus.

The design of a rough mill for the production of interior furniture parts is used to illustrate a simulation technique for analyzing and evaluating established and proposed sequential production systems. Distributions representing the real-world random characteristics of lumber and equipment feed speeds and delay times are programed into the simulation.

7. Araman, Philip A.
1977. Converting low-grade yellow-poplar lumber into furniture dimension stock. Proc. 5th Annu. Hardwood Symp. Hardwood Res. Counc. p. 74-80.

Low-grade yellow-poplar lumber was converted into lumber core furniture material and interior parts by several roughmill cut-up methods. The least-cost grade for core material was 2A Common lumber and either 2B or 2A Common should be used for interior parts. Manufacturing sequences that use gang-ripping first should be seriously considered when planning a new facility to produce core material and/or interior parts.

8. Arens, Edward and Donald Ballanti.
1977. Outdoor comfort of pedestrians in cities. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 115-129.

The outdoor comfort of pedestrians has been neglected by architects and planners because of difficulties in determining comfortable and uncomfortable climatic conditions and predicting the climatic characteristics of a planned urban site. Available information on comfort in a cold environment is summarized. The mechanical effects of wind on comfort are better understood than the thermal effects of climate and have proved to be practical criteria for assessing pedestrian comfort in designs. Climate-prediction techniques and a procedure for determining the probability of discomfort on a proposed site are described.

9. Auchmoody, L. R.
1977. Influence of mortality in evaluating forest growth responses to fertilization. Agron. Abstr. 1977 Annu. Meet. Los Angeles, Calif. p. 180.

10. Auchmoody, L. R.
1978. Hardwood fertilization progress: Allegheny and Appalachian areas. Allegheny News, Soc. Am. For. p. 10-11.

11. Auchmoody, L.R., and H. Clay Smith.
1977. Response of yellow-poplar and red oak to fertilization in West Virginia. Soil Sci. Soc. Am. J. 41: 803-807, illus.

Fertilization tests with small sawlog-size yellow-poplar and red oak were begun in the northern mountain section of West Virginia in the spring of 1970. During the first year, N was broadcast at 336 kg/ha, P at 97 kg/ha, and K at 93 kg/ha, in the second season, 112 kg/ha of N and 97 kg/ha of P. In response to N over a 3-year period there was a 47% increase in basal area of yellow-poplar and a 29% increase in red oak. There was no response to P, either alone or in combination with N. Negative effects on basal-area growth were observed where KCI was applied. Foliar response in leaf weight and color was attributed mostly to N, although P in combination with N produced slightly heavier and darker green leaves than N alone. Foliar N in yellow-poplar corresponding to the best basal-area growth was about 3.0% N.

12. Aylor, Donald E.
1977. Some physical and psychological aspects of noise attenuation by vegetation. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 229-233.

The physical mechanisms governing sound attenuation by foliage, stems and ground are reviewed. Reflection of sound energy is found to be the primary mechanism. In addition, new experimental results are discussed that help to quantify the psychological effect of a plant

barrier on perceived noise level. Listeners judged the loudness of noise transmitted through hemlock trees and through a minimal fence barrier to differ by as much as 7 dB even though the sound level at the listener was the same.

13. Bahr, G.F., W.F. Engler, and H.M. Mazzone.
1976. Determination of the mass of viruses by quantitative electron microscopy. Q. Rev. Biophys. 9: 459-489.

A transmission electron microscopy procedure was evaluated for its capacity to obtain the mass value of viruses. The transmission value through the image of virus particles recorded on a plate or film is measured and compared to that through the image of a standard particle whose mass is known; the mass value of the virus particles is determined and an average mass calculated. Among the viruses analyzed were the nucleopolyhedrosis viruses of the gypsy moth (Lymantria dispar, Linnaeus) and the European pine sawfly (Neodiprion sertifer, Geoffroy). The mass value data were required for registration of the insect viruses by the Environmental Protection Agency.

14. Barger Jack H.
1977. Improved sanitation practice for control of Dutch elm disease. U.S. Dep. Agric. For. Serv. Res. Pap. NE-386. 4 p.

In Detroit, Michigan, 12 plots, each containing about 600 American elm trees, Ulmus americana L., were subjected for 3 years to intensive and conventional sanitation treatments to control Dutch elm disease. In the intensive treatment, three disease surveys were conducted each year; each followed by tree removal within 20 working days. In the conventional treatment, one survey was conducted each year, and diseased trees were removed in late fall and winter. Results showed that the intensive sanitation treatment was significantly better than the conventional treatment each year.

15. Barger, Jack H.
1978. Smaller European elm bark beetle panel tests, 1975. Insecticide and Acaricide Tests 3: 143.

16. Barger, Jack H.
1978. Smaller European elm bark beetle elm bole bioassay tests, 1976. Insecticide and Acaricide Tests 3: 142.

17. Barger, Jack H., David P. Worley, and William N. Cannon, Jr.
1977. Effective Dutch elm disease control by early discovery and quick removal. In Proc. 32nd Annu. Conf. Dutch Elm Dis. Coop. Ext. Serv. Univ. Mass. Coop. Mass. For. Park Assoc. Oct. 5, 1977, Waltham, Mass. p. 6-12.

In Detroit, Michigan, 12 plots, each containing about 600 American elm trees, received intensive or conventional sanitation treatments over a 3-year period. In the intensive treatment on six plots, three disease surveys were conducted each year, each followed by tree removal within 20 working days. In the conventional treatment on six plots, one survey was conducted each year, and diseased trees were removed in late fall and winter. The survival of elms under the intensive treatment was significantly superior to that under the conventional treatment over all 3 years.

18. Barnard, Joseph E.
1978. Example of a specific regional inventory: The United States northeastern double sampling with partial replacement design. Proc. Joint Meet. IUFRO Groups S4 02 and S4 04. Bucharest, 18-26 June, 1978. p. 620-628.

The application of double sampling with partial replacement to the reinventory of 105 million acres (42.5 million ha) in the northeastern United States is discussed. Specific details of the application are provided. Special considerations such as data processing and local data summaries also are discussed.

19. Barnard, Joseph E.
1978. The FINSYS data-processing system--development, maintenance, experience. In Application of electronic data processing in forest inventory. Working Group 2 4.02.4 IUFRO.

Forest-inventory data processing requires quick, low-cost procedures for developing desired information. A computer system--FINSYS--is presented here. It is a generalized system with the flexibility to allow the user to specify the procedures for both data handling and table construction. The components of the system are described, and its development and use since 1964 are discussed.

20. Barnard, Joseph E.
1978. A tool for the processing of integrated resource inventory data. In Proc. Integrated Inventories of Renewable Natural Resources Workshop. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. RM-55. p. 332-335.

21. Barnard, Joseph E. and J. David Born.
1978. FINSYS-2: Subsystem EDIT - 2. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-43. 68 p., illus.

A computer software package for the editing of resource inventory data is described. The flexibility of the system in performing user-designated functions also is described. Full instructions for the operation of the system are included.

22. Barnard, Joseph E., and Teresa M. Bowers.
1977. A preview of Kentucky's forest resource. U.S. Dep. Agric. For. Serv. Res. Note NE-234. 11 p.

Forty-eight percent of the total land area of Kentucky is forest. Sixty-three percent of this forest land is the oak-hickory forest type and 47 percent of the forest area supports sawtimber stands. There has been a 23-percent increase in the volume of growing stock and a 24-percent increase in the volume of sawtimber

since the 1963 inventory. Total volume of growing stock is 11.4 billion cubic feet, and the sawtimber component is 27.6 billion board feet.

23. Barnard, Joseph E. and Teresa M. Bowers.
1977. A preview of West Virginia's forest resource. U.S. Dep. Agric. For. Serv. Res. Note NE-249. 11 p.

Forest land occupies 75 percent of the total land area of West Virginia. Sixty percent of the forest land is classified in the oak-hickory forest type and only 6 percent in all the softwood forest types. Since 1961, growing-stock volume has increased 24 percent. Yellow-poplar increased 39 percent in volume and is now the prevalent species in the State.

24. Benjamin, John C., George H. Moeller, and Douglas A. Morrison.
1977. Measuring environmental attitudes of elementary school students. In Children, Nature, and the Urban Environment: Symp. Proc. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-30. p. 95-100, illus.

A modified semantic differential was developed to measure environmental attitudes of sixth-graders. Classes were selected to represent different socioeconomic and residence backgrounds and degrees of previous exposure to structured environmental programs. Results indicate that: exposure to environmental education fosters favorable environmental attitudes; socioeconomic background and exposure to environmental education do not influence attitudes toward familiar, nonwater natural elements; urban students from low socioeconomic neighborhoods are unfamiliar with natural processes involving water resources; attitudes most easily transferred identify man as a contributor to environmental problems; and attitudes most difficult to transfer deal with ecological processes. Results provide a way to measure children's environmental attitudes and suggest a way to develop environmental programs for specific student groups.

25. Berger, Michael L.
1977. Environmental perceptions of residents of a multifunctional building. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 377-381.

A multifunctional building in which residents could live, work, and entertain themselves without contact with the surrounding external urban environment is the subject of this study. To what extent do inhabitants of this structure perceive their thermal and acoustical environments within the building to be different from or similar to those outside? To what degree are discrete climatic and sound zones perceived within the structure itself? What factors account for such perceptions? Answers to these questions were provided by an analysis of the responses by 246 residents of the John Hancock Center in Chicago to a mail questionnaire.

26. Berry, Frederick H.
1977. Decay in yellow-poplar, maple, black gum, and ash in the central hardwood region. U.S. Dep. Agric. For. Serv. Res. Note. NE-242. 4 p.

In a study of decay in yellow-poplar (*Liriodendron tulipifera* L.), red maple(*Acer rubrum* L.), sugar maple (*Acer saccharum* Marsh.), black gum (*Nyssa sylvatica* Marsh.), and ash (*Fraxinus* spp.) in the central hardwood region, decay was found in 57 of 148 study trees. Extent of decay, causal fungi, and method of entry are discussed. The relationship between tree age and diameter and decay is also examined.

27. Berry, Frederick H.
1977. Decay in oak inoculated with four heart-rot fungi. (abstr.) Am. Phytopathol. Soc. Proc. 3: 215-216.

Three oak species--scarlet (*Q. coccinea* Muenchh.), black, (*Q. velutina* Lam.), and white (*Q. alba* L.)--were artificially inoculated with pure cultures of the heart-rot fungi *Phlebia chrysocrea* (Berk. et Curt. in Berk.) Burds.; *Polyporus compactus* Overh.; *P. sulphureus* Bull. ex. Fr.; and *Poria andersonii* (Ell. &

Ev.) Neuman. Five years after inoculation, 120 trees (half of those inoculated) were felled and cut into sections. There were no significant differences among the four species in the upward and downward rate of spread of the fungi from the point of inoculation; but there were differences in the total vertical spread of decay. Decay progresses most rapidly in scarlet oak; Phlebia chrysocrea caused the greatest amount of decay.

28. Berry, Frederick H.
1977. Control of walnut anthracnose with fungicides in a black walnut plantation. Plant Dis. Rep. 61: 378-379.

Benomyl, chlorothalonil, cupric hydroxide, dodine, and maneb were significantly more effective in controlling anthracnose (Gnomonia leptostyla) in a 7-year-old black walnut plantation than no treatment. Application of benomyl resulted in significantly less disease development than when the trees were sprayed with dodine, which is presently the only fungicide registered for control of walnut anthracnose.

29. Berry, Frederick H.
1978. Decay associated with borer wounds in living oaks. U.S. Dep. Agric. For. Serv. Res. Note NE-268. 2 p.

Wood-borer wounds serve as entry courts for decay fungi in oak species in the central hardwood region. Thirteen species of fungi were isolated from decayed areas surrounding borer galleries. Polyporus compactus was the most frequently isolated fungus, accounting for about 1/3 of the total decay volume caused by identified fungi.

30. Berry, Frederick H., and Frances F. Lombard.
1978. Basidiomycetes associated with decay of living oak trees. U.S. Dep. Agric. For. Serv. Res. Pap. NE-413. 8 p.

Thirty-one identified species of wood-rotting hymenomycetes were associated with decay and cull in upland oak stands in Illinois, Indiana, Kentucky, Missouri, and Ohio. Seven of these species produced brown rots that

accounted for a volume loss of approximately 381 $ft^3$ in the trees sampled. The remaining species produced white rots that were associated with a volume loss of approximately 557 $ft^3$. Stereum frustulatum, Inonotus andersonii, Polyporus compactus, S. gausapatum, and Phlebia chrysocrea were the most frequently encountered species, accounting for 70 percent of the white-rot infections; 79 percent of the brown-rot infections were caused by Laetiporus sulphureus, Poria oleracea, and P. cocos.

31. Bevins, M.I. and D.P. Wilcox.
1977. National market analysis: Developed camping and related activities, 93 pages (mimeo). Vermont Agric. Exp. Stn., Burlington.

32. Biller, Cleveland J.
1977. A hydraulic assist for a manual skyline lock. U.S. Dep. Agric. For. Serv. Res. Note NE-247. 2 p., illus.

A hydraulic locking mechanism was designed to replace the manual skyline lock on a small standing skyline with gravity carriage. It improved the efficiency of the operation by reducing setup and takedown times and reduced the hazard to the crew.

33. Biller, Cleveland J., and Harry G. Gibson.
1978. Testing the Chuball for selective logging on Appalachian slopes. North. Logger 26(12): 18-19, 34, illus.

The CHUBALL is an experimental logging device, a ball made of two hollow steel hemispheres joined so that each can rotate independently. The ball can be used for logging difficult slopes. Because it is spherical, it will bounce off obstacles as it rolls downhill to return the winch line to the choker setters. The tests showed that operating costs and safety limitations are major deterrents to its widespread use.

34. Birch, Martin C., Richard W. Bushing, Timothy D. Paine, Stephen L. Clement and P. Dean Smith.
1977. Pheromone traps to suppress populations of the smaller European elm bark beetle. Calif. Agric. 31(11):4-6.

35. Birch, Thomas W., and Neal P. Kingsley.
1978. The forest-land owners of West Virginia. U.S. Dep. Agric. For. Serv. Resour. Bull. NE-58. 76 p., illus.

A statistical-analytical report on the owners of privately owned commercial forest land in West Virginia. The study was conducted in conjunction with the third forest survey of West Virginia by the Forest Service, U.S. Department of Agriculture. Statistical findings are based on responses of owners to a mailed questionnaire. Also included are trends in forest-land ownership and the attitudes and intentions of owners toward owning forest land, timber management, timber harvesting, and recreational use.

36. Bishop, Dwight E., and Myles A. Simpson.
1977. Outside and inside noise exposure in urban and suburban areas. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 183-194.

In urban and suburban areas of the United States (away from major airports), the outdoor noise environment usually depends strongly on local vehicular traffic. By relating traffic flow to population density, a model of outdoor noise exposure has been developed for estimating the cumulative 24-hour noise exposure based upon the population density of the area. This noise model has been used to provide first-order estimates of noise exposure in urban areas of this country. The model also can be used to estimate the variation in noise levels in communities and to plan community noise surveys. Field measurements at 100 locations throughout the country have shown good agreement with this model.

37. Bjorkbom, John C., and Rodney G. Larson.
1977. The Tionesta Scenic and Research Natural Areas. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-31. 24 p., illus.

A brief history and description of the Tionesta Scenic and Research Natural Areas in northwestern Pennsylvania. These areas are a remnant of the hemlock-beech climax forest that once covered 6 million acres of the Allegheny Plateau in Pennsylvania and New York. Changes that have occurred in this forest are described, and the trees, shrubs, herbs, and vertebrates present in the climax forest are listed.

38. Blackburn, Thomas.
1977. Washington's "free" 300-Station microscale weather network. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 98-108.

This article is intended to encourage those planning to conduct meso- or microscale weather studies to supplement their sophisticated observing techniques and equipment with low-cost observations taken by volunteers. Such observations can often show high benefits per unit cost by expanding the geographical area of study, increasing the density of observations, or verifying the validity of urban study findings. Techniques used in recruiting and sustaining the 300-station volunteer network in Washington, D.C., are described.

39. Blanchard, R. O., and W. C. Shortle.
1977. Changes in electrical resistance associated with disease and death of elm seedlings. Proc. Am. Phytopathol. Soc. 4: 183.

40. Blanchard, Robert O., Desmond Smith, Alex L. Shigo, and L. O. Safford.
1978. Effects of soil-applied potassium on cation distribution around wounds in red maple. Can. J. For. Res. 8: 228-231, illus.

Cation levels around wounds were evaluated to determine rate of concentration and relation of net increase to availability following soil amendments. Forty trees in four clones of 6-year-old red maple were paired by stem size. Half the clones were amended with soil-applied potassium chloride at 450 kg potassium/hectare. One tree of each pair was wounded and one pair of trees from each clone was harvested each week for 5 weeks. Concentrations of K, Mg, and Mn around wound sites and comparable sites on nonwounded trees were determined for each harvest. Concentrations of the elements in wounded tissues increased significantly over the 5-week period. Addition of K to the soil did not appear to influence concentrations of Mg or Mn in wounded or nonwounded tissues.

41. Blum, Barton M.
1977. Animal damage to young spruce and fir in Maine. U.S. Dep. Agric. For. Serv. Res. Note NE-231. 4 p., illus.

The loss of terminal buds on small balsam fir (Abies balsamea (L.) Mill.) and spruce (Picea spp.) trees because of nipping by mammals or birds has increased on the Penobscot Experimental Forest in recent years. The cut stem is smooth and slightly angled; there is no sign of tearing. Unnipped trees grew about 13 percent more than the nipped trees; the nipped trees showed less vigor in the lateral bud that took over as leader.

42. Blyth, James E., and James T. Bones.
1977. Veneer log production in the Northeast and North-central States in 1976. North. Logger 26(5): 10.

From a survey of veneer producers in the Northeast and North-central States in 1976, veneer-log production and receipts by states and regions are presented. Comparisons are made with a similar survey made in 1972 in the 21-state area. The article contains the number of veneer plants operating in 1976.

43. Blyth, James E., and James T. Bones.
1978. Pulpwood production in the Northeast and North Central states in 1977. North. Logger 27 (6): 18.

Pulpwood production increased 6 percent between 1976 and 1977 in the 21-state area. These statistics and others resulted from a complete canvass of eastern wood pulp mills conducted annually by the Forest Service Experiment Stations. The article contains 1977 pulpwood production statistics by states and sources of pulpwood and the number of mills that were operating.

44. Bond, Robert S. and Charles H. Wolf.
1978. Status and outlook of bonded Canadian woodworkers in Maine. North. Logger 26(11): 6-7, 44.

Employment of bonded Canadians in timber harvesting in Northern Maine has declined to fewer than 1000 persons or about one-fifth as many as in the 1950's. Replacement of these nonimmigrants by unemployed domestic workers is hindered by the lack of experience on the part of domestic workers and a reluctance to live in logging camps. Changes in harvesting technology, immigration laws, and the organization of the labor force should continue to reduce employer dependence on bonded workers.

45. Bones, James T.
1977. Residues for energy in New England. North. Logger 25(12): 20-22, 34, illus.

Future shortages of oil and natural gas, rising fuel costs, and stricter pollution regulations will make burning wood residue increasingly attractive. Most observers agree that the wood products industry has a unique potential to generate its own fuel, avoiding some costs. Progress toward energy self-sufficiency, however, will come step by step and will require major research and capital investment.

46. Bones James T.
1978. The forest resources of West Virginia. U.S. Dep. Agric. For. Serv. Resour. Bull. NE-56. 105 p., illus.

A statistical and analytical report of the third forest survey of West Virginia by the Forest Service, U.S. Department of Agriculture. Findings are based on the remeasurement of 1/5-acre plots and new 10-point cluster plots. This report analyzes trends in forest land area, timber volume, annual growth, and timber removals. Timber products output by forest industries, based upon a canvass of industries in 1974, and the importance of timber and forests to the State's economy and environment are also discussed. The report includes a discussion of the outlook for timber supplies during the next 30 years, a discussion of resource management opportunities, and 65 tables of statistical data.

47. Bones, James T., and James E. Blyth.
1977. Pulpwood production in the Northeast and North Central States in 1976. North. Logger 26(3): 22.

Between 1975 and 1976, pulpwood production increased 14 percent in the 21-state area. These statistics and others resulted from a complete canvass of eastern woodpulp mills conducted annually by the Forest Service experiment stations. The article contains 1976 pulpwood production statistics by states and sources of pulpwood and the number of mills that were operating.

48. Bones, James T., and John E. Brodie.
1977. The timber industries of Maryland. U.S. Dep. Agric. For. Serv. Resour. Bull. NE-52. 20 p., illus.

The result of a complete survey of the timber industries of Maryland, this report contains statistics about industrial timber production and receipts, and production and disposition of the manufacturing residues. Comparisons are made with the most recent previous survey, and trends in industrial wood output are noted.

49. Bones, James T., and David R. Dickson.
1977. Pulpwood--1976. U.S. Dep. Agric. For. Serv. Resour. Bull. NE-53. 23 p., illus.

An annual assessment of regional timber output based upon canvasses of the pulpmills in the Northeast. Contains data about pulpwood production from roundwood in the 14 northeastern states by counties and species groups, pulpwood chip production from plant residues, and production of total-tree chips. Pulpwood production between 1975 and 1976 increased 14 percent; roundwood production was up 12 percent and chipped residue production was up 21 percent. Trends in pulpwood production for the past 14 years are shown along with a list of the woodpulp mills that received northeastern pulpwood during 1976.

50. Bones, James T. and David R. Dickson.
1978. Veneer, 1976--A periodic assessment of regional timber output. U.S. Dep. Agric, For. Serv. Resour. Bull. NE-55. 13 p., illus.

A periodic assessment of regional timber output based upon a canvass of the veneer plants in the Northeast. Contains data about veneer-log production and receipts by states and species, log shipments between states and regions, and the disposition of the residues generated in the manufacture of veneer. Veneer log production between 1972 and 1976 increased 4 percent and northeastern veneer plant receipts decreased 2 percent. Trends in production and an outlook for the industry are presented along with a list of veneer plants in the Northeast.

51. Bones, James T., and Ralph P. Glover, Jr.
1977. The timber industries of West Virginia. U.S. Dep. Agric. For. Serv. Resour. Bull. NE-47. 16 p., illus.

The results of a complete survey of the timber industries of West Virginia. The report contains statistics about industrial roundwood production and receipts, and production and disposition of the manufacturing residues that result. Comparisons are made with the previous survey, and trends in industrial wood output are noted.

52. Bones, James T., and Chauncey J. Lohr.
1977. The timber resources of Kentucky. U.S. Dep. Agric. For. Serv. Resour. Bull. NE-50. 26 p., illus.

The results of a complete survey of the timber industries of Kentucky. The report contains statistics about industrial timber production and receipts, and production and disposition of the manufacturing residues that result. Comparisons are made with the most recent previous survey, and trends in industrial timber output are noted.

53. Bornstein, Robert D., and Yam-Tong Tam.
1977. Anthropogenic moisture production and its effect on boundary-layer circulations over New York City. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 36-52.

A heat and moisture excess over New York City is shown by helicopter soundings of temperature and set-bulb depression. The temporal and spatial distribution of anthropogenic moisture emissions in New York City were estimated from fuel-usage data. The URBMET urban boundary-layer model was used to evaluate the effects on the dynamics of the urban boundary layer resulting from the observed urban moisture excess. Work is currently in progress to determine the fraction of the observed moisture excess over New York that is anthropogenic.

54. Borthwick, J. O., G. Reethof, O. H. McDaniel, and D. E. Carlson.
1977. Attenuation of highway noise by narrow forest belts. (Abstr.) J. Acoust. Soc. Am. 62 Suppl. 1:S42-S43.

55. Braham, Roscoe R., Jr.
1977. Overview of urban climate. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 3-17.

The broad features of urban climate anomalies are described and explained by combining recent METROMEX data with those from prior studies. The urban heat island is well understood, and urban effects upon cloud nuclei and cloud microstructure are clearly observed and explained in part; but the causes of urban effects upon rainfall remain speculative.

56. Bringi, Sreedevi Krishnamurthy.
1978. Methodology of forest-tree selection for air pollution studies. MS Thesis, Ohio State Univ., Columbus. 85 p.

57. Brodie, John E., and Jean Nolley.
1978. Maryland's primary wood industry: a utilization summary and directory. MD. For. Serv., in cooperation with U.S. Dep. Agric. For. Serv. Northeast. For. Exp. Stn. 47 p.

58. Brown, S. E. and H. M. Mazzone.
1977. Electrophoretic studies in the development of the gypsy moth with special reference to isoenzymes. J. N.Y. Entomol. Soc. 85: 26-35.

59. Campana, R. J., and G. Gregory.
1976. Dutch elm disease control by pressure-injected solubilized MBC-HCL and excision of infected branch systems. (Abstr.) Proc. Am. Phytopathol. Soc. 3: 324.

60. Campbell, Robert W.
1978. Some effects of gypsy moth density on rate of development, pupation time, and fecundity. Ann. Entomol. Soc. Am. 71: 442-448.

61. Campbell, Robert W., and Ronald J. Sloan.
1977. Forest stand responses to defoliation by the gypsy moth. For. Sci. Monogr. 19. 34 p.

Records accumulated between 1911 and 1931 from plots in eastern New England were analyzed to determine forest changes following defoliation by the gypsy moth. Oak

trees required about 10 years to recover fully from a single heavy defoliation. Dominant trees were degraded less than subdominants and were less likely to die. Trees in poor condition were more likely to die after defoliation than oak trees. Red maple was more likely to die after defoliation than white pine. Repeated defoliation resulted in more and more one-storied stands. Differential loss rates among favored and non-favored food species tended to alter forest composition toward less susceptible types. Certain trees within any given tree species were consistently defoliated more heavily than others. These trees were also more likely to die.

62. Campbell, Robert W., and Ronald J. Sloan.
1977. Natural regulation of innocuous gypsy moth populations. Environ. Entomol. 6: 315-322.

Results of preliminary studies on numerical stability among a series of sparse gypsy moth populations studied between 1975 and 1970 supported the hypothesis that year-to-year numerical stability among these populations was determined largely by a combination of predaceous birds, which tended to concentrate on instar IV-VI larvae, and small mammals, especially Peromyscus leucopus, which tended to concentrate on pupae. The results also indicated that vertebrate predators were consuming about half of the parasitized instar IV-VI larvae, and most of the parasitized pupae.

63. Campbell, Robert W., and Ronald J. Sloan.
1977. Release of gypsy moth populations from innocuous levels. Environ. Entomol. 6: 322-330, illus.

Populations of the gypsy moth, Lymantria dispar (L.), tend to increase numerically from innocuous levels where there are abundant sheltered resting and pupation locations that reduce the probability that the growing insects will be eaten by vertebrates. These sheltered locations may be found anywhere within the environment, and they may occur naturally or be introduced by man; they are usually above the forest floor, close to or part of a suitable host tree, and dark, dry, and rough.

64. Campbell, Robert W., and Ronald J. Sloan.
1978. Numerical bimodality among North American gypsy moth populations. Environ. Entomol. 7:641-646, illus.

North American gypsy moth populations can be contained indefinitely within a sparse density range. Conversely, outbreaks can persist for up to a decade. Both the transition from sparse to outbreak and from outbreak to sparse tend to be abrupt. The study and management of these populations should be based largely on the realization that the overall system can behave in a numerically bimodal way.

65. Campbell, Robert W., and Ronald J. Sloan.
1978. Natural maintenance and decline of gypsy moth outbreaks. Environ. Entomol. 7:389-395.

In North America, area-wide outbreaks by the gypsy moth, Lymantria dispar (L.), have persisted for as much as a decade. The analysis of records accumulated on this insect throughout the northeastern United States indicates that such outbreaks are most likely to persist from one year to the next when insect densities range widely among the subpopulations in the overall population system. Area-wide outbreaks are likely to decline during years when numerical variability is minimal among the subpopulations. To be accurate, future projections of the natural maintenance and decline of area-wide outbreaks must account for the intrapopulation phenomena that give rise to these results.

66. Campbell, Robert W., Ronald J. Sloan, and Cynthia E. Biazak.
1977. Sources of mortality among late instar gypsy moth larvae in sparse populations. Environ. Entomol. 6:865-871.

Survival of instar IV-VI gypsy moths, Lymantria dispar (L.), in a sparse and numerically stable population near Eastford, Conn., was inversely correlated with larval density. Larvae that rested in bark flaps during the day were more likely to survive than those

that rested in the forest litter. Since few of these insects were killed by parasites or disease, we believe that most of them were eaten by density-dependent predators that can forage in the litter; our results suggest that predaceous birds were important in determining the survival rate of larvae in this sparse, stable population. The results also suggest that predator densities in this particular area were always sufficient to remove most of these larvae.

67. Cannon, William N., Jr., Jack H. Barger and David P. Worley.
1977. Dutch elm disease control: intensive sanitation and survey economics. U.S. Dep. Agric. For. Serv. Res. Pap. NE-387. 10 p., illus.

Recent research has shown that prompt removal of diseased elms reduces the incidence of Dutch elm disease more than the sanitation practice that allows diseased elms to remain standing into the dormant season. The key to prompt removal is repeated surveys to detect diseased elms as early as possible. Intensive sanitation can save more elms and cost less than the more conventional sanitation practice. A 3-year case history demonstrates savings of 25 percent in total cost and an additional 92 elms per thousand.

68. Cannon, W. N., Jr., J. H. Barger, and D. P. Worley.
1977. Intensive sanitation program shows cost savings of 25% in Dutch elm disease control. Park Maint. 39(12): 10-13. (Reprint of U.S. Dep. Agric. For. Serv. Res. Pap. NE-387).

69. Carl, Clayton M., Jr., and Harry W. Yawney.
1977. Fall versus spring sowing of sugar maple seed in a nursery. Tree Planters' Notes 28 (3 and 4): 24-26, 31, illus.

We compared germination and seedling development between sugar maple seeds sown in the fall and seeds that were stratified for 38, 49, and 60 days and sown in the spring. After one growing season, seedlings from fall-sown seeds were superior in survival and

height growth to those from spring-sown seeds. Because some sugar maple seeds apparently require a longer stratification period than others, none of the three spring treatments tested satisfied the germination requirements for all seeds; however, all of the seeds that were sown in the fall germinated.

70. Carlson, D., O. H. McDaniel, and G. Reethof.
1977. Layered media model for ground absorption. Inter-Noise 77. Vol. 2.

71. Carlson, D. E., O. H. McDaniel, and G. Reethof.
1977. Layered media model for ground absorption. (Abstr.) J. Acoust. Soc. Am. 62 Suppl. 1:S42.

72. Caswell, Stephanie J., and Karl Jakus.
1977. Role of land use planning in noise control. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 242-253.

A method for controlling outdoor noise through land use planning utilizes a computer model that broadly assesses the likely noise environments of a community on the basis of generalized land use and highway noise production and transmission conditions. The method is designed to enable town planners and other community decision-makers to identify those general areas that are potentially unsuitable for noise-sensitive types of development such as housing. The method also predicts probable changes in noise environments and in the suitability of those environments due to general changes in land use (development). The method does not require site-specific measurements.

73. Church, Thomas W., Jr.
1977. Industrial fuel - a solution to your tie-disposal problem. Crossties 58(3): 26-28.

Disposal of old crossties has become a major problem for railroads. By converting them into industrial fuel, the 2 million tons of old ties removed from track each year could be burned without polluting the environment.

Nationally, this tie fuel would conserve the equivalent of 4-1/2 million barrels of oil per year. At present, the cost of recycling old ties for fuel would exceed the railroads' return from marketing the fuel. However, selling tie fuel would reduce current disposal costs by at least 40 cents per tie.

74. Cicerello, Ronald R.
1978. Age and growth of largemouth bass, Micropterus salmoides (Lacepede), and bluegill, Lepomis Macrochirus robineque, in two unfertilized strip mine ponds in Breathitt County, Ky. 133 p. August 1978. M.S. thesis, Eastern Kentucky Univ.

75. Clark, F. Bryan.
1977. The central hardwood forest. In Central Hardwood Forest Conf. Proc. p. 1-9. South. Ill. Univ., Carbondale.

Defines the central hardwood forest, its boundaries and general plant associations. Past and present conditions are discussed along with factors likely to influence the future of this vast resource.

76. Clark, F. Bryan.
1978. Science and the Society of American Foresters. J. For. 76: 617.

Describes the present science programs of the Society of American Foresters and recommends changes.

77. Clark, F. Bryan.
1978. Biological potential of hardwoods: How to capture it. In Resource availability and the hardwood forest products industry. Proc. 1977 John S. Wright For. Conf., Purdue Univ. p. 27-39.

Most hardwood forest sites have retained their capacity for production despite past treatment, including heavy cutting. However, the growth potential varies widely with species composition and site quality. There are good opportunities to improve the growth of selected

high-quality trees. Technology is available to recapture the biological potential of neglected hardwood forests but the private owner needs advice and assistance.

78. Coleman, Derek J.
1977. Ecology of an urban park. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 351-354.

A controversial issue in the city of Kitchener, Ontario, involves the proposed extension of a boulevard through Lakeside Park. A study of this proposal revealed several facets of human interrelations with an urban park. Most important, there was a large gap between the perception and the reality of its environmental quality. This has several practical implications in planning parks in the city.

79. Coleman, Ronald E.
1977. SEMTAP (Serpentine End Match TApe Program). U.S. Dep. Agric. For. Serv. Res. Pap. NE-384. 5 p., illus.

SEMTAP (Serpentine End Match TApe Program) is an easy and inexpensive method of programming a numerically controlled router for the manufacture of SEM (Serpentine End Matching) joints. The SEMTAP computer program allows the user to issue commands that will accurately direct a numerically controlled router along any SEM path. The user need not be a computer programmer to produce a variety of SEM patterns.

80. Cook, David I., and David F. Van Haverbeke.
1977. Suburban noise control with plant materials and solid barriers. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 234-241.

Studies were conducted in suburban settings with specially designed noise screens consisting of combinations of plant materials and solid barriers. The reduction in sound level is reported, and tentative recommendations are made for the use of plant materials and solid barriers in noise screens.

81. Corbett, E. S.
1977. Land Use. In W.E. Sopper, J.A. Lynch, and E.S. Corbett, eds. Water resources at the forest-urban interface. U.S. Dep. Agric. For. Serv. Pinchot Inst. Environ. For. Res. PA-2. p. 14-17.

The North Atlantic region contains only 5% of the nation's land area, but 25% of the national population. The extreme concentration of urban development is indicated by the fact that almost 87% of the land area is occupied by cropland, pasture, or forest, while 82% of the region's population lives on the remaining 13%. The effects of land use changes on the hydrology of an area and on sedimentation in urban environments is discussed and research needs outlined.

82. Corbett, E. S.
1977. Publication education and acceptance. In W.E. Sopper, J.A. Lynch, and E.S. Corbett, eds. Water resources at the forest-urban interface. U.S. Dep. Agric. For. Serv. Pinchot Inst. Environ. For. Res. PA-2. p. 46-47.

Health, social, political, and economic considerations, in addition to physical and technical aspects, are important in gaining a complete perspective for the utilization of wastewater. The public can play a key role in blocking approaches considered acceptable by those designing systems of wastewater disposal. For an idea such as recycling urban sewage and sludge on the land to be put into effect in our society, it must have public acceptance. The diffusion and adoption of new ideas is discussed. Resistance to change by individuals and institutions and principles to consider in developing educational programs for wastewater utilization are outlined along with research needs.

83. Corbett, E. S.
1977. Recreation. In W.E. Sopper, J.A. Lynch, and E.S. Corbett, eds. Water resources at the forest-urban interface. U.S. Dep. Agric. For. Serv. Pinchot Inst. Environ. For. Res. PA-2. p. 17-22.

Municipal watersheds in megalopolis have been providing quality water for domestic use (as well as timber products and municipal income) for many years. However, they are also a recreational and aesthetic resource. Benefits derived from these resources are human experiences which are produced and enjoyed on the site. The impacts of recreation-associated use on water quality are discussed and case histories are used as examples. Policy implications and research needs are outlined.

84. Corbett, Edward S., James A. Lynch, and William E. Sopper.
1978. Timber harvesting practices and water quality in the eastern United States. J. For. 76: 484-488, illus.

Data from forested experimental watersheds in the eastern United States indicate that leaching of nutrients after timber harvesting, especially clearcutting, tends to increase from south to north, while increases in streamwater temperature and sediment loadings tend to decrease. Concentrations of nutrients in streamwater are highest where revegetation of cutover areas is delayed. Also, increased streamwater temperature (in addition to increased light) caused by exposing stream channels may influence water quality by affecting a wide range of physical, chemical, and biological processes. Soil erosion losses from harvesting operations can be kept to acceptable levels by following available land management guidelines, and with supervision by qualified foresters. Buffer strips, in which only light selection cutting is allowed, will help minimize sedimentation as well as nutrient leaching and stream temperature increases.

85. Cowling, Ellis, B., and Leon S. Dochinger.
1978. The changing chemistry of precipitation and its effects on vegetation and materials. Am. Inst. Chem. Eng. Symp. Ser. 74: 134-142.

86. Crawford, H. S.
1976. Integrating deer habitat evaluation into forest land use planning. Proc. 10th Northeast Deer Study Group, Yarmouth, Nova Scotia, Canada, September 1974. p. 6-14.

87. Crawford, H. S. and W. L. Stutzman.
1977. Measuring deer habitat attributes with microwave signal attenuation. In Trans. 11th Meet. Northern Deer Study Group, Quebec City, P.Q., Sept. 1975. p. 123-132.

88. Cuppett, Donald G.
1977. Use of solar energy in drying lumber. In Practical application of solar energy to wood processing. (Va. Polytech. Inst. and State Univ. Workshop Proc.) For. Prod. Res. Soc., Madison, Wis. p. 62-64.

Summarizes world-wide research and development of solar dry kilns and suggests how U.S. firms can apply existing knowledge to small-scale drying operations. Also proposes new research required to enable wider use of solar energy to heat large scale commercial kilns and low-temperature dryers. Author's research in solar-assisted low-temperature drying found immediate potential for construction of new units to utilize substantial amounts of solar heat in the drying process.

89. Cuppett, Donald G., and David M. Emanuel.
1978. Yield of utility boards from No. 2B Common yellow-poplar lumber. In Marketing and utilization of yellow-poplar: Symp. Proc. Knoxville TN March 21-22, 1978. Inst. Agric. Univ. Tenn. p. 151-157.

90. Curtis, Willie R.
1977. Hydrologic aspects of surface mining in the East. Proc. Soc. Am. For. 1977: 152-157.

Surface mining drastically disturbs the land; it may change the hydrology of watersheds and adversely affect water quality. Proper reclamation and prompt revegetation can minimize these effects, and some of the changes may even be advantageous because detention and retention storage capacities may be increased.

91. Curtis, Willie R.
1977. Sampling for water quality. In William H. Kirchhoff (ed.), Methods and standards for environmental measurement. Proc. 8th Materials Res. Symp. Gaithersburg, MD. 1976. U.S. Dep. Commer., Natl. Bur. Stand. p. 237-244.

Samples collected weekly from six first-order streams in eastern Kentucky over seven water years were used to determine what frequency of sampling would provide the best estimate of water quality from the fewest samples. Results indicate that baseline water quality can be adequately defined by sampling every 2 weeks for 1 year. Biweekly sampling was also adequate during and immediately after surface mining. Monthly sampling was found to be generally adequate a year or more after mining was completed. Regression analyses indicated that specific conductance can be used to estimate the concentrations of dissolved solids and of dissociated ions such as calcium, magnesium, and sulfate.

92. Curtis, Willie R.
1977. Surface mining and the flood of April 1977. U.S. Dep. Agric. For. Serv. Res. Note NE-248. 4 p., illus.

Data from experimental sites in Breathitt County, Kentucky, and Raleigh County, West Virginia, showed that during a major rainstorm on 4 April 1977 streamflow from surface-mined watersheds peaked lower than that from adjacent or nearby unmined watersheds.

93. Curtis, Willie R.
1978. Hydrologic aspects of surface mining in the East. In Proc. Soc. Am. For. 1977 Natl. Conv., Oct. 2-6, Albuquerque, N.M. p. 152-157.

94. Curtis, Willie R., and Michael J. Superfesky.
1977. Erosion of surface-mine spoils. Proc. 32nd Annu. Meet. Soil Conserv. Soc. Am. p. 154-158.

New mining and reclamation techniques such as returning spoil to approximate original contour and head-of-hollow construction have not been evaluated to determine

their potential for causing erosion and sedimentation. A study was made of the effects of time, precipitation, and position on the slope on erosion on a reclaimed back-to-contour slope in Caryville, Tenn., and on the outslope of a head-of-hollow fill in Breathitt County, Ky. Erosion at Caryville totaled 1.30 inches (33.02 mm) from 23 August 1974 through 27 April 1976, or 235 tons/acre (526.8 t/ha). Erosion at the Breathitt County site totaled 0.94 inch (23.8 mm) from 16 May 1973 through 22 July 1975, or 170 tons/acre (381 t/ha). Results also indicated that long uninterrupted spoil slopes are conducive to the formation of rills and gullies. Although these soil losses were measured over 26 months in Kentucky and over 20 months in Tennessee, the amount of material that actually left the disturbed area was not determined.

95. Cuscino, Thomas A., Robert Jennings Heinsohn, and Clotworthy Birnie, Jr.
    1977. Fugitive dust from vehicles travelling on unpaved roads. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 295-302.

A model has been developed for estimating concentrations of fugitive dust downwind of an unpaved road within a factor of 2 for most cases. The model allows for winds oblique to the road and also for extraction of fugitive dust from the plume as it diffuses to the ground. Experiments were performed to determine the accuracy of the model in estimating downwind concentrations of fugitive dust generated by a vehicle travelling on a gravel road.

96. Cushwa, Charles T., and Joseph E. Barnard, and Robert B. Barnes.
    1978. Trends in woodcock habitat in the United States. In Proc. 6th Woodcock Symp. Fredericton, New Brunswick. p. 31-38.

Timber data from national reports for 1963 and 1970 were summarized and their implications for woodcock (*Philophela minor*) habitat in 30 states interpreted.

This analysis indicated a net gain in potential woodcock breeding habitat in 19 states of 2,715,095 ha and a net gain of 3,658,438 ha of potential winter habitat in 11 states. Published area data on potential woodcock habitat are highly variable, indicating that we do not have accurate or complete summaries of available data. Several activities to improve the data base on woodcock habitat are recommended.

97. Cuthbert, R.A. J.W. Peacock, and W.N. Cannon, Jr. 1977. An estimate of the effectiveness of pheromone-baited traps for the suppression of Scolytus multistriatus (Coleoptera: Scolytidae). J. Chem. Ecol. 3: 527-537, illus.

We attempted to suppress a population of Scolytus multistriatus (Marsham), the principal vector of Dutch elm disease, by trapping flying beetles on sticky traps baited with synthetic pheromone. The estimated catch on 421 traps distributed throughout a 1-$km^2$ plot in Detroit, Michigan, was nearly 1 million beetles. Because as estimated 5 million beetles emerged in the plot during the study period, we conclude that this preliminary trapping study had no appreciable effect on suppressing the population. Studies that employ improved materials and techniques are continuing.

98. Cuthbert, Roy A., and John W. Peacock. 1978. Response of the elm bark beetle, Scolytus multistriatus (Coleoptera: Scolytidae), to component mixtures and doses of the pheromone multilure. J. Chem. Ecol. 4: 363-373, illus.

The response of the elm bark beetle, Scolytus multistriatus (Marsham), to various doses and mixtures of the three components of its aggregation pheromone was measured. The ratio of the components released, particularly heptanol to multistriatin, strongly influenced the number, but not the sex ratio, of beetles that responsed. We concluded that a bait that released about 400: 100: 800 yg/day of heptanol-multistriatin-cubebene would be effective in mass-trapping beetles

99. Czapowskyj, Miroslaw M.
1977. Status of fertilization and nutrition research in northern forest types. In Proc. Symp. Intensive Culture of Northern Forest Types. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-29. p. 185-203.

Forest fertilization is a useful tool that, when combined with other silvicultural practices, results in increased forest growth. Many experiments have demonstrated that both hardwoods and conifers of the northern forest respond to the addition of one or more nutrients. Examples of pitfalls and successes are given. Present status of research and future research needs are discussed.

100. Czapowskyj, Miroslaw M.
1977. Hybrid poplar on two anthracite coal mine spoils: 10-year results. U.S. Dep. Agric. For. Serv. Res. Note NE-268. 4 p.

101. Czapowskyj, Miroslaw M., Robert V. Rourke, and Robert M. Frank.
1977. Strip clearcutting did not degrade the site in a spruce-fir forest in central Maine. U.S. Dep. Agric. For. Serv. Res. Pap. NE-367. 8 p.

Changes in nutrient concentration in the forest floor and in the mineral soil were assessed on a mature spruce-fir stand in central Maine that had been harvested in 1965 by strip clearcutting. On part of the site, slash was left in place; on other parts it was removed, and on some it was burned. Eight years after the harvest, the clearcut areas tended to have increased pH and increased concentrations of bases and percentages of base saturation, but the amounts of N and P were comparable to those in the residual forest. Soil drainage class and differences in parent material were the major sources of variation. There were no significant differences between controls and slash-disposal treatments or among treatments. There was no evidence of site degradation from strip clearcutting.

102. Daft, M. J., and E. Hacskaylo.
1977. Growth of endomycorrhizal and nonmycorrhizal red maple seedlings in sand and anthracite spoil. For. Sci. 23: 207-216.

The growth of red maple was increased when the plants, grown in either sand or anthracite waste containing bonemeal, were infected with Glomus macrocarpus var. geosporus or Gigaspora gigantea, respectively. The importance of phosphate and nitrate for normal development was shown in plants grown in sand culture. Mycorrhizal plants grown in sand or anthracite contained more phosphorus than nonmycorrhizal plants. Effects of the various nutrient treatments and mycorrhizal infection on the size of the plants, leaf numbers, leaf areas, stem anatomy, and chemical composition of the plant tissues are reported. Both the secondary and beaded tertiary roots became infected with the fungal endophytes. The possibility of exploiting this symbiosis on anthracite spoil areas is discussed.

103. Davidson, Walter H.
1977. Performance of ponderosa pine on bituminous mine spoils in Pennsylvania. U.S. Dep. Agric. For. Serv. Res. Pap. NE-358. 6 p., illus.

Seedlings from 40 seed sources of ponderosa pine (Pinus ponderosa Laws.) were planted on a strip-mine spoil in central Pennsylvania in 1969. Survival of seedlings from different sources ranged from 23 to 90 percent after six growing seasons. The average height of the seedlings ranged from 67 to 140 cm for the same period. Eight sources produced seedlings that were average or above in both height growth and survival.

104. Davidson, Walter H.
1977. Birch species survive well on problem coal mine spoils. Northeast For. Tree Improve. Conf. Proc. 24: 95-101.

Seven species of birches from 10 seed sources were evaluated for survival and growth rates on coal mine

spoils in Pennsylvania. The seedlings were planted on eight very acidic strip-mine spoil areas, pH 3.0 to 3.8, and one acidic strip-mine area, pH 3.3. After 3 years, survival was rated satisfactory to good on all the spoil areas. Birches from three sources did not survive satisfactorily on the deep-mine refuse. Height evaluations were biased by damage caused by browsing deer. Nevertheless, a few seedlings attained heights of 200 cm or more. Paper birch from a northeastern seed source is recommended for reclamation plantings in Pennsylvania.

105. Davidson, Walter H.
1978. Genetic variation of ponderosa pine provenances on Pennsylvania coal-mine spoils. (Abstr.) 4th North Am. For. Biol. Workshop Proc. Syracuse, N.Y. p. 194.

106. Davidson, Walter H., and Jane Riddle.
1978. Old strip mine produces . . . new pulpwood crop. Pa. For. 68(2): 18.

107. DeBald, Paul, Dick Kennell, Dick Watt, and Dave Worley.
1976. Silviculture + economics = good timber marking. In Proc. 1st State For. Manage. Conf. Perrysville, Ohio. U.S. Dep. Agric. For. Serv. Northeast. Area State and Priv. For., Upper Darby, Pa. p. 91-102.

Describes a timber-marking procedure for intermediate cuts that combines silvicultural considerations with economic guidelines. Explains how the procedure works and, with examples, shows why it works. Emphasizes the procedure's usefulness in marking timber for multiple-use objectives and in measuring in investment terms the timber growing opportunities given up to achieve other goals.

108. DeBlois, R. W., E. E. Uzgiris, D. H. Cluxton and H. M. Mazzone.
1977. Comparative measurements of size and polydispersity of several insect viruses. General Electric Corp. Tech. Rep. #77CRD250, December 1977.

109. DeGraaf, R. M.
1977. Common residents--the suburban birds. In Birds and their habitats in Amherst, Massachusetts. P. Westover (ed.). Hitchcock Center for the Environment. p. 14-22.

This chapter in a locally-published booklet presents the basic natural history of some common year-round and summer birds of southern New England. Basic behavior, nest sites and foods are presented for 22 species, along with some hits for attracting them.

110. DeGraaf, R. M.
1977. Bringing in the birds. Mass. Wildl. 28(5):14-17.

111. DeGraaf, R. M.
1978. The importance of birds in ecosystems. In R.M. DeGraaf, Tech. Coord., Proc. Workshop on Nongame Bird Habitat Management in the Coniferous Forests of the Western United States. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. PNW-64.

112. DeGraaf, R. M.
1978. New life from dead trees. Natl. Wildl. 16(4): 28-31.

113. DeGraaf, R. M. (Technical Coordinator)
1978. Management of southern forests for nongame birds. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. SE-14. 176 p.

114. DeGraaf, R. M. (Technical Coordinator)
1978. Proceedings nongame bird habitat management in the coniferous forests of the western United States. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. PNW-64. 100 p.

115. DeGraaf, R. M., H. R. Pywell, and J. W. Thomas.
1977. Relationships between nest height, vegetation, and housing density in New England suburbs. Trans. 32nd Fish and Wildl. Conf. p. 130-150.

This paper presents the patterns of distribution of nesting birds in a suburban town and the nest-site preferences of 13 bird species. A total of 1653 nests, representing 21 bird species, were found in five categories of housing density; results showed that total nesting density was significantly higher in low-density suburbs. More crowded suburbs and business districts had significantly lower nest densities than expected. Nest site preference indices were calculated for 13 bird species--all revealed pronounced nesting preferences among available tree and shrub species.

116. DeWalle, D. R., and R. E. Jackobs.
1977. Trees around properties cut home heating costs. Sci. in Agric. 24 (4):9.

117. Dickerson, A. Laverne
1977. The Youth Conservation Corps and adolescents' self-concept. In: Children, Nature, and the Urban Environment. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-30. p. 143-149.

118. DiMartino, David R.
1977. Relocation within the urban environment. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 382-388.

Analysis of motives indicates that minimal consideration is given to the physical environment when urban households select from among alternative residential locations. There is a greater awareness of, and response to, the economic and social conditions of the residential environment among movers. When the motivations of highly-educated white-collar professionals are correlated with their household characteristics and

residency experience few variables discriminate at all between those who view the physical environment as an important motive for relocation, and those who do not. The physical environment is cited more frequently (and considered more important) during the relocation process by owners of residences, rather than renters.

119. Dindal, D., and L. Levintan.
1977. The soil invertebrate community of composting toilet systems. Proc. VI Colloq. Soil Zool. Uppsala, Sweden.

120. Dixon, W. N., M. W. Houseweart, and Daniel T. Jennings.
1978. How to examine branches for spruce budworm egg masses. Coop. For. Res. Unit, School of For. Resour. Univ. Maine, Orono. 16 p.

121. Dixon, Wayne N., Mark W. Houseweart, and Daniel T. Jennings.
1978. How to examine branches for spruce budworm egg masses. CANUSA/CFRU. 18 p.

122. Dochinger, Leon S.
1977. Effects of soil applications of acidified solutions on growth and survival of forest tree species. (Abstr.) Proc. Am. Phytopathol. Soc. 3: 304.

123. Dochinger, Leon S., and Stanford L. Arner.
1978. Needle mottle in eastern white pine seedlings: A selective parameter for air pollution sensitivity. U.S. Dep. Agric. For. Serv. Res. Pap. NE-406. 5 p., illus.

Positive correlations were established between morphological characteristics in eastern white pine seedlings and subsequent tolerance or sensitivity to air pollution 5 and 7 years after outplanting in Ohio plantations. Of 11 seedling variables, needle mottling was an accurate indicator of sensitivity or tolerance to air pollution. This characteristic, which may be genetically controlled, should allow for the detection and removal of sensitive white pines in the nursery during grading.

124. Dochinger, Leon S., and Jack G. Calvert.
1978. Air pollution sources: General effects and trends. In New directions in Century 3, strategies for land and water use. Soil Conserv. Soc. Am. Proc. 33: 187-193.

Interest in air pollution has intensified throughout the world because of the continual increases in waste emissions and their cumulative deposition on the earth's surfaces. These aerial wastes may be potentially beneficial in small quantities but harmful in larger amounts; and soil, water, and vegetation are the primary biological sinks for them. Decisions that involve economic and environmental tradeoffs for clean energy must be made with consideration of the long-term consequences of ambient pollution in the biosphere.

125. Dochinger, Leon S., and Ellis B. Cowling.
1978. Impact of acid precipitation on forest freshwater ecosystems in Norway. J. Water, Air, and Soil Pollut. 8: 389-390.

Report summarizes accomplishments of the interdisciplinary Norwegian research project "Acid precipitation - Effects on forest and fish." Research considerations should be provided for precipitation monitoring of the fluctuations of acidity in the forest environment and to developing realistic and ecologically safe plans for curtailing possible adverse effects of acidity on natural resources.

126. Dochinger, Leon S., and Eva J. Pell.
1976. Forest and air relationships: Research priorities in the Northeast. Northeast. For. Comm. RP-2.05-1. p. 1-18.

A task force has identified research priorities related to northeastern forests and air pollution: (1) assessment of the impact of air pollution, (2) aicd precipitation and the forest ecosystem, (3) cleansing the air of pollutants by forest trees, and (4) genetic bases for tolerance of air pollution in forest tree species. This research needs a long-term coordinated interdisciplinary approach to provide the information needed for maintaining forest productivity and conserving the forest environment.

127. Donley, David E.
1978. Oviposition by the red oak borer, Enaphalodes rufulus Coleoptera: Cerambycidae. Ann. Entomol. Soc. Am. 71: 497-498, illus.

Oviposition and host preference tests were conducted with red oak borer, Enaphalodes rufulus (Haldemann), collected at the Scioto Trail State Forest, Ohio. Multiple matings were common but unmated females did not lay eggs. Forty-five females laid an average of 119 eggs, in a 19-day average oviposition period. Egg viability averaged 99 percent. Host preference tests indicated that the red oak borer prefers northern red oak, black oak, and scarlet oak over white oak for oviposition. When oak wood is not avialable, females lay only 4 percent of their eggs on species such as black walnut, white ash, shagbark hickory, red maple, and American elm. Oviposition sites are in bark cracks under bark scales, and under lichen patches.

128. Donley, David E., and J. Ronald Terry.
1977. How to identify damage by major oak borers in the eastern United States. U.S. Dep. Agric. For. Serv., Northeast. For. Exp. Stn. (Unnumbered publ.)

129. Donnelly, John R.
1977. Morphological and physiological factors affecting formation of adventitious roots on sugar maple stem cuttings. U.S. Dep. Agric. For. Serv. Res. Pap. NE-365. 5 p., illus.

Sugar maple cuttings were collected twice a week throughout June from four mature trees. Some of the cuttings were analyzed for carbohydrate (starch and sugars) and nitrogen content; the others were stuck in rooting beds. Rooting response showed significant daily and clonal variations. Cuttings rooted best when their terminal leaves were mature, as judged by size and color. Daily changes in rooting response were only weakly correlated with sugar and nitrogen concentrations, but rooting response peaked soon after a marked rise in starch.

130. Doskotch, R. T. M. O'Dell, and P. A. Godwin.
1977. Feeding responses of gypsy moth larvae, Lymantria dispar, to extracts of plant leaves. Environ. Entomol. 6: 563-566.

Feeding response of larvae of the gypsy moth (Lymantria dispar L.) to 30 plant leaf extracts is reported. Plant extract is incorporated into a basal diet of cellulose powder, agar, and water. The amount of feeding was measured by dry weight of frass produced in 24 h. Extracts were tested alone and in combination with a stimulatory plant residue; this allowed classification of extracts into four categories: stimulant; neutral (no feeding effect); deterrent; and synergist.

131. Duthie, A. H., K. M. Nilson, H. V. Atherton, and L. D. Garrett.
1977. Proposed score card for yogurt. Cultured Dairy Prod. J. Aug: 10-12. (Vt. Agric. Exp. Stn. J. No. 359).

A study designed to produce a new maple yogurt product also produced a new score card for evaluating natural flavored yogurts. The scoring system evaluates color, body and texture, and flavor. The technique was used in developing a Swedish-style natural maple flavored yogurt.

132. Duthie, A. H., Suzanne Wulff, K. M. Nilson, H. V. Atherton and L. D. Garrett.
1977. Flavor panel selects all-natural maple yogurt. Cult. Dairy Prod. J., (Nov.): 8-10.

133. Dyer, Kenneth L., and Willie R. Curtis.
1977. Effect of strip mining on water quality in small streams in eastern Kentucky, 1967-1975. U.S. Dep. Agric. For. Serv. Res. Pap. NE-372. 13 p., illus.

Eight years of streamflow data are analyzed to show the effects of strip mining for coal on chemical quality of water in six first-order streams in Breathitt Co., Ky. Data are presented on stream

discharge, turbidity, conductivity, pH, $SO_4$, Cl, $HCO_3$, Ca, Mg, Na, K, Fe, Al, Mn and Zn. Concentrations of most major dissolved constituents increased greatly during mining, reached a maximum a year or two after mining had ceased, then held steady for several years. Average stream pH values increased from about 6.8 before mining to about 7.4 after strip mining.

134. Echelberger, Herbert E., and George H. Moeller.
1977. Use and users of the Cranberry Backcountry in West Virginia: Insights for eastern backcountry management. U.S. Dep. Agric. For. Serv. Res. Pap. NE-363. 8 p., illus.

Users of the Cranberry Backcountry in West Virginia were sampled to learn their preferences and opinions about conditions, facilities, and management options, and to collect demographic data. Their responses were compared with those of western Wilderness Area visitors. The results may help managers make better informed decisions.

135. Economic Development Council of Northeastern Pennsylvania.
1977. Human needs served by outdoor recreation in northeastern Pennsylvania, 1977. Unnumbered Misc. Publ., 50 p.

136. Edwardh, Joey.
1977. Residential settings: effects of home and neighborhood on the quality of life for old people. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 389-398.

The author discusses the role of home and neighborhood in the lives of old people and explores the impact of the physical and social organization of these spaces on an old person's perception of his immediate environment and his subsequent activity patterns. Home and neighborhood reinforce an old person's sense of identity and mediate between the old person and the larger society. Information

about the meaning of home and neighborhood in the lives of old people contributes to the data available to those making the decisions that affect the distribution of social and physical resources in our cities.

137. Ellefson, Paul V., and Gilbert P. Dempsey.
1977. Promotion: a step toward sound Christmas tree marketing. Colo. For. Prod. Mark. Bull. 11(4): 4-5.

138. Emanuel, David M.
1978. Processing hardwood bark residues by screening. U.S. Dep. Agric. For. Serv. Res. Note NE-260. 3 p.

Most of the hardwood bark residues removed by floating-cutterhead or rosserhead debarkers can be processed into acceptable bark products by screening alone. And by prescreening bark residues, operators of bark processing plants can use smaller hammermills than otherwise are required, thus lowering investment and energy costs.

139. Fabos, Julius Gy.
1977. Composite landscape assessment: Assessment procedures for special resources, hazards and development suitability. Part II of the Metropolitan Landscape Planning Model (METLAND). Mass. Agric. Exp. Stn. Amherst, Bull. No. 637. 323 p.

140. Fabos, Julius Gy, and Kimball H. Ferris.
1977. A computerized model for integrating the physical environmental factors into metropolitan landscape planning. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 422-431.

This paper justifies and illustrates (in simplified form) a landscape planning approach to the environmental management of the metropolitan landscape. The

model utilizes a computerized assessment and mapping system, a recent advance in computer technology that allows for greater accuracy and the weighting of different values in mapping at the regional scale. It assesses resource, hazardous, and developmentally suitable areas to determine the consequences of development in these areas, and to channel development to the most environmentally appropriate areas.

141. Fahrer, Victor S., and Howard A. Peters.
1977. Use of a land-use-based emissions inventory in delineating clean-air zones. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. P. 263-272.

First the methodology used to establish a land-use-based emission inventory is described. Then this inventory is used as input in a simple model that delineates clean air and buffer zones. The model is applied to the town of Burlington, Massachusetts. Conclusions and recommendations are offered for the model's use and for interpretation of its results.

142. Fay. S. C. and R. E. Leonard.
1977. Handling backcountry privy wastes by bin composting. Appalachia (Dec.): 118-122.

143. Fay, S. C. and R. H. Walke.
1977. The composting option for human waste disposal in the backcountry. U.S. Dep. Agric. For. Serv. Res. Note NE-246. 3 p.

The disposal of human waste by composting at backcountry recreation areas is a possible alternative to methods that are considered unsafe. The literature indicates that aerobic, thermophilic composting is a reliable disposal method that can be low in cost and in maintenance. A bark-sewage mixture can be composted to produce a pathogen-free substance that might be used in site rehabilitation. Composting in a leakproof bin is odorless, and is largely independent of site conditions.

144. Federer, C. A.
1976. A SPAC model for transpiration and the availability of soil water. (Abstr.) Bull. Am. Meteorol. Soc. 57:1408.

145. Federer, C. A.
1977. Lead resistance and xylem potential differ among broadleaved species. For. Sci. 23: 411-419, illus.

Mean leaf diffusive resistance in unstressed trees and shrubs of 27 species in New Hampshire and southern Maine ranged only from 215 to 4.5 s/cm after normalizing to 15 mbar vapor pressure deficit. One species, Spiraea latifolia, had a higher resistance, 5.8 s/cm. During water stress, stomata partially closed at xylem pressure potentials that differed among genera, averaging -15 bar for Betula, -17 for Populus, -21 for Quercus, and -23 for Prunus. The potentials did not decrease further as resistances increased. Stressed Quercus and Prunus seedlings had lower potentials than did larger trees.

146. Federer, C. Anthony.
1978. Review of Water and Plant Life: Problems and Modern Approaches. For. Sci. 24: 140.

147. Felix, Robert, and Alex L. Shigo.
1977. Rots and rods. J. Arboric. 3(10): 187-190, illus.

Trees with internal rot, or crotches likely to split, can be helped by proper bracing. Although the holes made for the bracing materials are wounds, and wounds start the processes that can lead to rot, the braces can extend the time that trees with rot and weak crotches can remain safe, attractive, and healthy. An understanding of how rots develop and how rods should be installed will help the arborist to maximize the benefits of proper tree bracing and to minimize the injury caused by the new wounds required for the bracing materials. Some basic information on the development of tree rots and installation of bracing is given.

148. Filip, Stanley M.
1977. High-yield silviculture for northern hardwoods. In High-yield forestry in northern hardwoods, spruce-fir and white pine. 24th Annu. Meet. Soc. Prot. N.H. For. Nov. 21, 1975, Concord. p. 2-4.

High-yield or "intensive" silviculture should be used to maximize the yield of high quality sawtimber in northern hardwoods. This management includes precommercial and commercial cuttings in even-aged stands, and stand improvement cuttings in uneven-aged stands. To encourage high proportions of yellow birch and paper birch, and some sugar maple and white ash, regeneration cuttings such as strips, shelterwood, or block clear-cutting with site preparation are needed.

149. Filip, Stanley M.
1977. How applicable is uneven-age management in northern forest types? In Proc. Symp. Intensive Culture of Northern Forest Types. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-29: 53-62.

For the proper application and practice of uneven-age management, one must consider residual stocking, maximum tree-size objective, and diameter distribution. All three components are described, and it is shown how they fit into a practical package for application in a timber tract.

150. Filip, Stanley M.
1978. Impact of beech bark disease on uneven-age management of a northern hardwood forest. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-45. 7 p., illus.

Beech bark disease disrupted stand development during 24 years of management under the single-tree selection system, leading to a deficiency of large sawtimber trees and lowered butt-log quality. Group selection in combination with single-tree selection is recommended for improving species composition and maintaining stand stocking and structure.

151. Fisher, Edward L.
1978. Measurement and abatement of noise in the timber harvesting industry. MSIE Thesis, West Virginia Univ., Morgantown.

152. Fisher, E. L., and H. G. Gibson.
1977. Helicopter moves east - trial results. Agric. Eng. 58(8): 17-18.

Encouraged by results of helicopter logging tests in other parts of the country, loggers in the East have been performing their own trials. There have been few helicopter logging operations in the eastern U.S., but a recent test in the Allegheny National Forest was efficient; there were few major delays. The average daily production rate for the entire operation was 205.90 $m^3$; the daily cost to the sawmill was $4,327.00.

153. Flower, Franklin B., Ida A. Leone, Edward F. Gilman, and John J. Arthur.
1977. Landfill gases and some effects on vegetation. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 315-322.

Gases from refuse landfills moving through soil were studied in New Jersey. The gases, products of anaerobic decomposition of organic matter in the refuse, injured and killed peach trees, ornamentals, and commercial farm crops. They are potential hazards to life and property because combustible gases can seep into residences. Remedial measures are described.

154. Frank, Robert M.
1977. Silvicultural options for obtaining high yields in spruce-fir. In High-yield forestry in northern hardwoods, spruce-fir and white pine. 24th Annu. Meet. Soc. Prot. N.H. For. Nov. 21, 1975, Concord. p. 5-9.

Presently, the selection, shelterwood, and clearcutting systems of silviculture are recommended for regenerating spruce-fir stands from seed. Future tending,

harvesting, and replacement may resemble farming, especially on better sites. Increases in yield from genetically improved growing stock, fertilization, intermediate cultural treatments, and full-tree harvesting may be more efficiently realized with even-age management. If multiple use of most of the forested area is the landowner's objective, uneven-age management is more efficient.

155. Frank, Robert M.
1977. Indications of silvicultural potential from long-term experiments in spruce-fir types. In Proc. Symp. Intensive Culture of Northern Forest Types. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-29. p. 159-177.

Data collected since the 1950s from commercial treatments on more than 400 acres in the Penobscot Experimental Forest in Maine indicate a high mortality rate --520 percent of net growth--in the woodland preserve where timber is not harvested, and a low mortality rate--16 percent of net growth--under the selection system. As the intensity of silvicultural treatment increased, periodic net annual growth increased from 10 cubic feet per acre (0.7 $m^3$/ha) in the woodland preserve to 56 cubic feet per acre (3.9 $m^3$/ha) under the selection system.

156. Gabriel, William J.
1978. Genetic variation in seed and fruit characters in sugar maple. U.S. Dep. Agric. For. Serv. Res. Pap. NE-404. 4 p., illus.

Genetic variation was found in dry weight of seed and percentage of filled fruit. Relations between latitude, percentage of filled fruit, and dry weight of seeds were variable; dry weight of seed exhibited a complex pattern of genetic variation.

157. Gabriel, William J., and Donald W. Seegrist.
1977. Phenotypic variation in sap sugar among sugar maple stands in Northeastern United States. Northeast. For. Tree Improv. Conf. Proc. 24: 41-49.

Sugar maple stands showed a high degree of heterogeneity in sugar content in sap. Differences within and between stands, and between states, were statistically significant. Two broad populations, based on sugar production, were apparent. Production in grazed and roadside stands was significantly higher than that in ungrazed stands, suggesting that stress may be important in sap sweetness of trees. Sugarbush means and standard deviations were correlated. Selection differentials for 43 selected trees averaged 2.54. Average sap-sugar content of trees in the study area was 2.5 percent. Plus trees were selected by the comparison-tree method.

158. Garbriel, William J., and Donald W. Seegrist. 1977. Differences in sugar content of sugar maple sap in northeastern United States. Natl. Maple Syrup Dig. 16(3): 8-10.

A high degree of difference was found in the sugar content in sap among sugarbushes in a 6-state area of the northeastern United States. Differences were statistically significant within and between states. Sugarbushes grazed by livestock or located along roads consistently produced sweeter sap than ungrazed bushes.

159. Galford, Jimmy R. 1977. Attempt at concentrating red oak borer eggs by providing artificial oviposition sites. U.S. Dep. Agric. For. Serv. Res. Note NE-232. 2 p.

Thirty-eight scarlet and 14 black oaks were spirally wrapped to a height of about 2 m with black or white cotton tape 2.5 cm wide in an attempt to increase oviposition of the red oak borer, Enaphalodes rufulus (Haldeman), on selected trap trees. However, only 57 eggs were laid under tape on 17 of the trees, all scarlet oaks. Attacks but no eggs were found on some of the wrapped black oaks.

160. Galford, Jimmy R.
1977. Evidence for a pheromone in the locust borer. U.S. Dep. Agric. For. Serv. Res. Note NE-240. 3 p.

Laboratory studies have suggested the existence of a pheromone in the locust borer. Male beetles spent more time on bolts of wood exposed to virgin females than on control bolts. The females apparently deposited the pheromone on the bolts of wood and on filter paper.

161. Galford, Jimmy R.
1978. A trap for tree-inhabiting cerambycids. U.S. Dep. Agric. For. Serv. Res. Note NE-258. 4 p., illus.

To determine species and numbers of insects visiting a tree, a paper trap for cerambycids was designed and tested on locust borers, Megacyllene robininae (Forster), and red oak borers, Enaphalodes rufulus (Haldeman), under plantation and forest conditions. Test results showed that the trap could be used successfully to capture locust borers but it requires some modification for red oak borers. Several other cerambycid species were also captured in the trap.

162. Gansner, David A., Owen W. Herrick, and Dietman W. Rose.
1977. Intensive culture on northern lands: trends, expectations, and needs. U.S. Dep. Agric. For. Serv. Res. Pap. NE-371. 8 p., illus.

Timber-stand improvement and commercial thinning are the practices most often used, and probably will continue to be. Increases in recent harvests due to intensive culture were estimated at about 4 percent. Managers expressed needs for more knowledge about genetic tree improvement, site preparation, fertilization, and species conversion.

163. Gansner, David A., Owen W. Herrick, and William B. White.
1978. Economic analysis of the gypsy moth problem in the Northeast. IV. Forest stand hazard ratings for gypsy moth. U.S. Dep. Agric. For. Serv. Res. Pap. NE-410. 3 p.

Provides a practical method for rating the potential hazard of impending gypsy moth attacks to forest stands. Stepwise multiple regression analysis is used to develop equations for estimating tree mortality from easy-to-measure key characteristics of stand condition.

164. Garrett, Lawrence D.
1977. Analysis of market factors associated with sales of cut natural Christmas trees. U.S. Dep. Agric. For. Serv. Res. Pap. NE-364. 14 p., illus.

Describes a study of natural Christmas tree retail marketing practices in Winston-Salem, N.C. Market analysis reveals that lots in areas of high retail activity sell more trees and obtain higher prices for trees sold.

165. Garrett, Lawrence D.
1977. Processing maple sugar with a vapor compression distiller: An economic analysis. U.S. Dep. Agric. For. Serv. Res. Pap. NE-385. 12 p., illus.

Evaluation of vapor compression distillers for processing maple syrup revealed that they are more energy-efficient than conventional evaporators, produce syrup of equal quality, and are effective in reducing total annual processing costs.

166. Garrett, Lawrence D.
1978. Production opportunities in Vermont. In Structural flakeboard from forest residues; proceedings of a symposium presented by the USDA Forest Service, June 6-8, Kansas City, Mo. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. WO-5. p. 172-177.

Opportunities for production of structural flakeboard in Vermont exist both in the supply of raw material and marketing of the final product. An analysis of economic impact of such factors as raw material supply, plant size, and product market price indicate feasibility at existing factor input costs and product prices. The analysis also revealed profitability to be highly sensitive to raw material cost and final product price. Price increases from increased competition for wood resource for energy generation or paper products could cause significant increases from increased competition for wood resource for energy generation or paper products could cause significant increases in final product price. Market acceptance is strongly predicted on a competitive price line with 1/2-inch CDX plywood.

167. Garrett, Lawrence D.
1978. The economic implications of using wood space heaters for home comfort heat. In Wood heating seminar 3 proc., p. 390-415. (Presented by the Continuing Educational Program of the Wood Energy Inst. with the Energy Ext. Serv. Univ. WI, April 3-6, 1978).

168. Garrett, Lawrence D., Howard Duchacek, Mariafranca Morselli, Frederick J. Laing, Neil K. Huyler, and James W. Marvin.
1977. Increasing the efficiency of maple sap evaporators with heat exchangers. U.S. Dep. Agric. For. Serv. Res. Pap. NE-388. 12 p., illus.

A study of the engineering and economic effects of heat exchangers in conventional maple syrup evaporators indicated that: (1) Efficiency was increased by 15 to 17 percent with heat exchangers; (2) Syrup produced in evaporators with heat exchangers was similar to syrup produced in conventional systems in flavor and in chemical and physical composition; and(3) Heat exchangers reduce per-unit production costs, and can yield greater production and higher profits.

169. Garrett, Lawrence D., and Mariafranca Morselli.
1978. Mechanical compression evaporators. Natl. Maple Syrup Dig. 18(4): 20-23.

An analysis of a vapor compression evaporator for processing maple syrup revealed that: (1) it evaporated 1 pound of water with .047 pounds of steam equivalent; similar plant capacity using open-pan evaporators required 1.5 pounds of steam to produce 1 pound of water; (2) it produced a syrup quality equal to that produced in a conventional open-pan evaporation plant using identical sap; and (3) the operation of a central plant producing 8,000 gallons of syrup per year using a vapor compression evaporator should yield a return of 12 to 16 percent on investment.

170. Garrett, Lawrence D., and Thomas H. Pendleton.
1977. Selling natural Christmas trees in an urban market. Am. Christmas Tree J. 21(3): 23-27.

A study of marketing practices by retailers in Winston-Salem, North Carolina, and Denver, Colorado, revealed that marketing strategies associated with effective sales of other consumer goods are also effective in marketing natural Christmas trees. The study identifies marketing factors important to increased sales of natural trees, including locating near areas of high retail activity, providing better parking facilities, using effective advertising media, and marketing quality products.

171. Garrett, Lawrence D., and Thomas H. Pendleton.
1977. Developing models to forecast sales of natural Christmas trees. U.S. Dep. Agric. For. Serv. Res. Pap. NE-374. 5 p.

Describes models developed for forcasting natural Christmas tree sales in metropolitan areas. Factor and regression analysis were used to isolate the market factors most closely associated with tree sales. Models were tested to show their effectiveness in other market areas.

172. Garrett, P. W.
1977. Interspecific hybridization: the American experience. Proc. Symp. on Eastern Cottonwood and Related Species. p. 156-164.

On the basis of previous work with species and species hybrids of the genus Populus there is ample evidence to suggest that improved clonal material can be produced in a relatively short period of time. Based on diversity of germ plasm, species crossability, ease of clonal propagation, age of flowering and other factors, this genus offers the greatest potential for genetic improvement. If we are to meet the predicted demands for wood fiber, it may be through plantings near mill locations and on the best available sites. The genus Populus is ideally suited for this purpose.

173. Garrett, P. W.
1978. Eastern white pine selection and breeding. Pa. Christmas Tree Growers' Assoc. Bull. 140. p. 16-17.

174. Garrett, P. W., and A. L. Shigo.
1978. Selecting trees for their response to wounding. Metrop. Tree Improv. Alliance Proc. 1: 69-72.

175. Garrett, P. W., A. L. Shigo, and J. Carter.
1976. Variation in diameter of central columns of discoloration in six hybrid poplar clones. Can. J. For. Res. 6: 475-477.

The percentage of stem diameter discolored in the center of hybrid poplar logs varied by clones. For the six clones studied, discoloration columns ranged in percentage of total stem diameter from 85.0 to 55.8.

176. Gatchell, Charles J., Ronald E. Coleman, and Hugh W. Reynolds.
1977. Machining the serpentine end-matched joint. Furn. Design & Manuf. 49(6): 30-32, 34, illus.

The serpentine end matched joint provides a method of obtaining greater yields from 2 Common and poorer lumber, using the precise machining afforded by numerical controlled routers. These routers can easily be

programmed with the aid of a computer. The machining of serpentine end matched joints in three preferred hardwood species has been perfected.

177. Gatchell, Charles J., Ronald E. Coleman, and Hugh W. Reynolds.
1977. Machining the serpentine end matched joint--a tool for improved utilization of low-grade lumber. Proc. 5th Annu. Hardwood Symp. Hardwood Res. Counc. p. 63-68, illus.

Serpentine end-matching joins two pieces of wood with an esthetically pleasing sine-wave-shaped butt joint. This new application for numerically controlled routers may increase the desirability of 2 Common lumber as a raw material. Problems encountered and overcome in machining the joint in black walnut, black cherry, and northern red oak are described. Values of machining variables for "perfect" joints in these species are listed.

179. Gerhold, H. D., and W. D. Bartoe II.
1976. Performance testing tree cultivars in metropolitan environments. J. Arboric. 2(12): 221-227.

180. Gibson, Lester P.
1977. Elm phloem necrosis distribution. Plant Dis. Rep. 61: 402-403, illus.

The author used a map to compare the known distribution of elm phloem necrosis in 1946 with that observed from 1971 to 1976. Observations made from 1971 to 1976 showed the incidence of phloem necrosis was on the increase and its distribution was expanding north-eastward as well as southward.

181. Gibson, Lester P.
1977. A new genus of Blacinae (Hymenoptera: Braconidae). Pac. Insects 17(2-3): 241-245, illus.

A new genus, Canalicephalus, of the subfamily Blacinae is described along with four new species, C. orientalis from Borneo, C. novus from New Guinea, and C. bakeri and C. mindanao, both from the Phillippines. Keys are included to separate these two genera and the four species.

182. Gibson, Lester P.
1977. Monograph of the genus Curculio in the new world (Coleoptera: Curculionidae). Part II. Mexico and Central America. Misc. Publ. Entomol. Soc. Am. 10(4). 52 p.

Detailed morphological and taxonomic characteristics of the genus Curculio L. are presented for all new species and general information is presented for all species known to occur in Mexico and Central America. A key to species is included. Twenty-seven species are included, of which 18 are described as new.

183. Glass, Norman R., Gene Likens, Leon Dochinger.
1978. The ecological effects of atmospheric deposition. (Abstr.) 3rd Natl. Conf. Interagency Energy/Environ. R&D Program. U.S. Environ. Prot. Agency. Washington, D.C. p. 7.

An increasing deposition of beneficial and injurious concentration of wet and dry acidic substances has occurred during the past two decades. Approximately 60% of the acidity in rainfall is attributable to acid sulfates and 40% to acid nitrate compounds. Impacts of acidity deposition on biosphere are reviewed and effects on ecological processes are discussed.

184. Godin, V. B., and R. E. Leonard.
1976. Guidelines for managing backcountry travel and usage. Trends. June, p. 33-37.

Methods for influencing the backcountry recreationist's choice of trail and campsite locations do not have to be of a prohibitive or regulatory nature. Four types of "barriers" for usage are discussed: administrative, oral, written, and natural. The last three methods are the least obtrusive and may be as effective in limiting use on fragile sites as the currently used, more expensive permit and reservation systems.

185. Godin, V. B. and R. E. Leonard.
1977. Who is violating the law of the land. Appalachia 41(4): 8-23.

186. Godin, V. B., and R. E. Leonard.
1977. Design capacity for backcountry recreation management planning. J. Soil Water Conserv. 32: 161-164.

Recreation managers are seeking ways to determine how many people a backcountry site can accommodate before resource degradation occurs. A "design capacity" approach to this problem offers more planning flexibility than the "carrying capacity" approach. The capacity of a site would depend not only on the ecological setting, but also on the amount of site maintenance that can be applied to reduce physical damage. An inventory of current backcountry maintenance costs would allow the forest manager to plan use levels and maintenance needs within his management area.

187. Godin, V. B. and R. E. Leonard.
1977. Design capacity for management decision-making. Proc. Quant. Ecol. Workshop, Coll. Life Sci. and Agric., Univ. N. H., Durham. p. 53-54.

188. Godin, Victor and Raymond Leonard.
1977. Permit compliance in eastern wilderness: Preliminary results. U.S. Dep. Agric. For. Serv. Res. Note NE-238. 3 p.

Sixty-eight percent of the visitors to a wilderness area in the White Mountain National Forest obtained the required travel permits during the summer of 1975. These data appear to follow patterns found in other such studies.

189. Godwin, Paul A., and Thomas M. ODell.
1977. Alternate hosts of Blepharipa pratensis (Meigen). U.S. Dep. Agric. For. Serv. Res. Note NE-245. 3 p.

A current tactic for biological control of the gypsy moth, Lymantria dispar Linnaeus, is to release its parasites in forests susceptible to gypsy moth damage before the gypsy moth arrives on the theory that the parasites can find and utilize native insects as hosts in the interim. Blepharipa pratensis is being used in this way. The efficacy of such releases has not been demonstrated, but we report here on the survival of B. pratensis in eight potential North American hosts.

190. Goodfriend, Lewis S.
1977. Range of sound levels in the outdoor environment. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 172-182.

Current methods of measuring and rating noise in a metropolitan area are examined, including real-time spectrum analysis and sound-level integration, producing a single-number value representing the noise impact for each hour or each day. Methods of rating noise for metropolitan areas are reviewed, and the various measures from multidimensional rating methods such as the Composite Noise Rating are examined, along with the trend towards single-number rating schemes. The reliability of the various noise-measurement and evaluation methods is discussed in terms of planning needs.

191. Goho, Curtis D.
1977. Logging a farm woodlot with a Farmi-winch. North. Logger 26(5): 14-15, 30-31, illus.

A Farmi-winch mounted on a farm tractor was used to harvest 52 Mbf on a 27-acre woodlot. Trees up to 26 inches dbh were bucked into logs, winched, and skidded to a landing. Road construction was avoided by using existing trails. A summary of logging times and delays is presented.

192. Gore, W. E. G. T. Pearce, G. N. Lanier, J. B. Simeone, R. M. Silverstein, J. W. Peacock and R. A. Cuthbert.
1977. Aggregation attractant of the European elm bark beetle, Scolytus multistriatus: Production of individual components and related aggregation behavior. J. Chem. Ecol. 3:429-446.

193. Górska-Brylass, A., E. Galoch, and Z. Porazinski.
1976. The dynamics of endogenous growth regulators during the development of male cones of Larix europea L. Acta Univ. Nicolai Copernici, Biol. XVIII, Nauki Math.-Przyr. 37: 33-38.

This preliminary study demonstrated seven well-defined developmental stages with large differences in assayable gibberellins and auxins. The level of free gibberellins rises, then falls slowly, whereas the level of extractable auxin is high only in the earliest stage and is uniformly low thereafter. A much more detailed study of this subject is necessary and is being undertaken.

194. Graber, Raymond.
1978. Summer planting of container-grown northern hardwoods. U.S. Dep. Agric. For. Serv. Res. Note NE-263. 5 p., illus.

Seedlings of paper birch and yellow birch were grown in styrofoam blocks of two cavity sizes, 40 cc and 125 cc, in four different soil mixes. After 16 weeks, the

seedlings were outplanted on a cleared forest site in mid-July. Seedling survival for all treatments after two growing seasons was very good (98.8 percent). The effects of container size and soil mix were relatively small and statistically significant only at the time of outplanting. Paper birch seedlings grew much more rapidly than the yellow birch. An early August outplanting of red maple seedlings was added to the study. Growth and survival of the red maple was similar to that of the birches.

195. Graber, Raymond E., and Donald F. Thompson.
1978. Seeds in the organic layers and soil of four beech-birch-maple stands. U.S. Dep. Agric. For. Serv. Res. Pap. NE-401. 8 p., illus.

Seeds contained in forest floor samples from four northern hardwood stands aged 5, 38, 95, and 200+ years were germinated. Thirty-five species of herbs, shrubs, and trees were identified. Seed numbers of the early successional species Rubus and pin cherry (Prunus pensylvanica L.f.) were highest in the two younger stands. If short rotations are used for timber harvesting, these plants may cause reduced stocking of high-value timber species.

196. Gratzer, Miklos A., James E. Sutherland, and Robert T. Throssell.
1978. Recreation in the Poconos: images and perceptions. Syracuse Univ. and New York Coll. of Environ. Sci. and For. Unnumbered Bull. 32 p.

197. Graves, Paul F., and Gilbert P. Dempsey.
1976. Forest economics, policy and program research priorities in the Northeast. Northeast Regional Plann. Comm. Res. Rep. 2.09, 40 p.

A cooperative product of the Northeast's land-grant universities and the Forest Service, the report delineates the need for research efforts in the realm of resource economics, policy, and programs to help develop an optimum interrelationship between

the Northeast's forest land, other resources, and people. The focus is upon processes critical to forest resource planning that encompass broad social considerations. Problem areas that require extensive research include public use conflicts, production of goods and services, management information systems, interorganizational relations, taxation, and research methodology.

198. Greene, John L.
1977. Two publicly sponsored assistance programs using private consultants. The Consultant 22(3):56-59.

199. Gregory, Garold F.
1977. Therapy and prophylaxis of Dutch elm disease (DED) by pressure injection of methyl 2-benzimidazole carbamate hydrochloride. (Abstr.) Am. Phytopathol. Soc. 3: 268.

200. Gregory, Garold F.
1977. Perspectives in DED control: 1977. In: Nat. Arborists Assoc. Symp. No. 1, The current state of the art of Dutch elm disease control, p. 32-35.

201. Gregory, R. A.
1977. Cambial activity and ray cell abundance in Acer saccharum. Can. J. Bot. 55: 2559-2564, illus.

The ray cell population of sugar maple wood is important because much of the sucrose found in maple sap is converted from starch stored in these cells, we found. We found that we could silviculturally manipulate the ratio of ray cells to other cell types by controlling radial growth rate; the unit area population of ray cells rose abruptly with accelerating growth rate. When fast growth was not maintained, the unit area population of ray cells slowly declined.

202. Gregory, Robert A.
1978. Living elements of the conducting secondary xylem of sugar maple (Acer saccharum Marsh.). Int. Assoc. Wood. Anat. Bull. 4:65-69, illus.

Living cell types of the conducting xylem of sugar maple were studied as a single interconnected protoplasmic unit (the symplast) to help understand and identify the mechanisms that control sap flow and secretion of sugar into sap. There are numerous cell types within the symplast which function in various ways, including storage, transport, secretion, and mechanical support.

203. Gregory, Robert A., and J. A. Romberger.
1977. The shoot apical ontogeny of the Picea abies seedling. IV. Protoxylem initiation and age of internodes. Am. J. Bot. 64: 631-634.

In Picea abies seedlings the distance below the base of the shoot apical dome to the first protoxylem (px) to be differentiated in the internodes beneath is a linear function of apical dome basal diameter. The morphogenic age in plastochrons and the chronometric age in days of the internode in which px is first differentiated were computed. As the seedlings age from 30 to 140 days, the distance from the base of the apical dome to px increases from 186 to 295 μm, the n of $n_{px}$ increases from 16 to 53, but the chronometric age of $n_{px}$ remains within the range of 10 to 12 days.

204. Grisez, Ted J.
1978. Pruning black cherry in understocked stands. U.S. Dep. Agric. For. Serv. Res. Pap. NE-395. 9 p., illus.

Black cherry trees 4 to 6 inches in dbh with live crown ratios ranging from 73 to 92 percent were pruned to 25, 50, or 75 percent of tree height or were left unpruned. Most trees can be pruned to 50 percent of tree height in one operation. Trees that have large crowns and that are fully exposed on the southwest side should be pruned less severely. Pruning to 75 percent of tree

height caused excessive epicormic branching, poor diameter growth, and serious inner bark and cambium necrosis.

205. Hacskaylo, E.
1976. Mycorrhizae in nursery management. Proc. 1974 Northeast. Nurserymen's Conf. p. 27-34.

Mycorrhizal associations are usually classed as ecto-, ectendo- and endomycorrhizae. These associations are essential in establishing vegetation in most habitats. Drained peat bogs in Sweden, Anthracite coal spoils, and soils in tropical Puerto Rico are areas where research has proved their value in tree survival. The fungi could be advantageously used for seedling nursery and container inoculum. Research is in progress to develop efficient means for their pratical use.

206. Hacskaylo, E.
1976. Activities within mycorrhizal associations at the root-soil interface. Proc. 16th IUFRO. p. 78-79. Oslo, Norway. 1976.

Exchanges of metabolites between tree roots and adjacent soil are usually intermediated by associated mycorrhizal fungi. The extent to which metabolites are modified while transversing the mycorrhizal system is only partially known. Nutrient uptake, carbohydrate metabolism, production of growth regulators and antibiotics and many other biotrophic interactions must be researched further in the laboratory and in natural environments.

207. Hacskaylo, E.
1977. Persistence and fruiting of ectomycorrhizal fungi in Puerto Rico. Proc. 3rd North Am. Conf. on Mycorrhizae. p. 54.

208. Hacskaylo, E.
1977. The role of root metabolites in ectomycorrhizal associations. Second Int. Mycol. Congr. 1: 256.

209. Hacskaylo, Edward.
1977. Review of Endomycorrhizas, F. E. Sanders, Barbara Mosse, and P. B. Tinker (eds). Mycologia 69: 212-214.

This book is a compilation of papers presented at a symposium on endomycorrhizae at the University of Leeds in July, 1974. There is a heavy emphasis on responses of plants to infections by vesicular-arbuscular mycorrhizal fungi, but orchid and ericaceous endomycorrhizae also are included.

210. Hacskaylo, E.
1978. Response of pine roots to growth substances. (Abstr.) Program abstracts, Joint Meeting IUFRO Working Party S2-01-13 and French Group for Root Studies. Nancy, France, Sept. 1978.

211. Hale, Kathy N., and David S. Canavera.
1977. Preliminary results of a white spruce (Picea glauca (Moench) Voss) half-sib progeny test in Maine. Proc. 25th Northeast. For. Tree. Improv. Conf. p. 94-103.

212. Halverson, Howard G.
1977. Potential urban runoff disposal in urban forests. (Abstr.) Am. Water Resour. Assoc. 1977 Conf., Tucson, Ariz. p. 15.

213. Hanks, Leland F.
1977. Hardwood tree grades and a plan for their implementation. Proc. 5th Annu. Hardwood Symp. Hardwood Res. Counc. p. 69-73.

Forest Service Hardwood Tree Grades for Factory Lumber, developed through research, are accompanied by board-foot lumber grade yields for 11 major hardwood species. Those conducting forest inventories or timber sale appraisals will find the grades useful. A plan for implementing use of the tree grades is also discussed; it may be followed by researchers working with both State and extension foresters to implement results of research.

214. Hanks, Leland F.
1977. Predicted cubic-foot yields of lumber, sawdust, and sawmill residue from the sawtimber portions of hardwood trees. U.S. Dep. Agric. For. Serv. Res. Pap. NE-380. 23 p.

Prediction equations and tables are given for estimating the gross cubic-foot volume of sawtimber for hardwood trees, and cubic-foot yields of lumber, sawdust, and sawmill residue that are produced during the sawing process. Yields are presented for northern red oak, black oak, white oak, chestnut oak, red maple, sugar maple, yellow-poplar, yellow birch, paper birch, and basswood.

215. Hansen, Bruce G.
1976. The ABC of trends in the Christmas tree industry. In Proc. Cornell Univ. School for Christmas Tree Growers, Ithaca, NY. p. 1-18, illus.

This article discusses the evolution of the American Christmas tree industry, with particular attention to changes in the American import market, the manufacture of artificial trees, and the American Christmas tree plantation during the past 20 years. In addition, the article provides a detailed look at recent operating characteristics of plantations in New York state.

216. Hansen, Bruce G.
1977. Goal programming: A new tool for the Christmas tree industry. U.S. Dep. Agric. For. Serv. Res. Pap. NE-378. 4 p.

Goal programming (GP) is applicable to decision-making in the natural Christmas tree industry. Its application is illustrated by a hypothetical decision facing two growers with different interests. A simplified presentation of the GP model plus an extended discussion of GP's suitability to the Christmas tree industry is included.

217. Hansen, Bruce.
1978. A new tool: goal programming. Am. Christmas Tree J. 22(3): 42-44.

Changes in the Christmas tree industry over the past 20 years have greatly increased the number, complexity, and importance of decisions made by Christmas tree growers. Using a hypothetical example, Goal Programming is offered as a tool to assist growers in the decisionmaking process. Through the application of Goal Programming, a variety of alternatives can be clearly delineated leading to a choice that gives explicit recognition to the trade-offs involved between achieving stated goals and working within given resource limitations.

218. Hansen, Bruce G., and Charles J. Gatchell.
1978. Serpentine end matching: A test of visual perception. U.S. Dep. Agric. For. Serv. Res. Pap. NE-408. 5 p., illus.

In tests of gross perception of serpentine end matched (Sem) joints in oak and cherry display panels, there were no significant differences between the number of times the non-Sem panels were chosen and the number of these selections that could be attributed to chance. Results of separate tests of sensitivity of perception of Sem joints showed that the most conspicuous joints in oak and cherry panels were chosen most often, and that the least conspicuous joints were detected least often. Given proper selection of pieces to be end matched, and moderate finishing, Sem joints are difficult to detect--even by those who are well-informed about Serpentine end matching.

219. Hay, C. J.
1976. Predisposition of woody vegetation to insects. In Air pollution and metropolitan woody vegetation. U.S. Dep. Agric. For. Serv. Pinchot. Inst. Environ. For. Study. p. 33-34.

220. Hay, C. John.
1977. The effects of insects and air pollutants on the health and survival of trees. Am. Nurseryman 146(9): 13, 109-114.

Low levels of air pollutants may possibly predispose trees to added insect stress. Virtually all feeding types of insects have been implicated. Scientists specializing in tree genetics, insects, diseases, and physiology at the USDA's Delaware, Ohio, research laboratory and at the Wooster, Ohio, OARDC laboratory are searching forest and shade tree species for specimens that are tolerant to several stress factors, including insects and air pollution.

221. Hay, C. John.
1977. Bibliography on Arthropoda and air pollution. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-34. 16 p.

This bibliography contains 227 references to literature published through 1976 concerning observations or experiments involving Arthropoda in association with gases and particles that pollute the air. References are listed in three sections: review papers, laboratory research, and field research. They are arranged by type of air pollutant: ozone, sulfur oxides, fluorides, and other pollutants. Each reference is indexed by tree host and arthropod species.

222. Hay, C. John, and Keith F. Jensen.
1977. Fumigation effects of $SO_2$ on pine needle scale infestations on eastern white pine. (Abstr.) Proc. Am. Phytopathol. Soc. 3: 305.

223. Healy, William, and E. Nenno.
1978. Turkey broods and hairy snoods. Turkey Call 5(3): 12-17.

What factors affect wild turkey productivity and survival? The complex interactions among weather habitat, predators, and poult survival were illustrated for sportsmen by describing what happened to 11

radio-tagged hens during the nesting and brood-rearing season. Habitat management is shown to be a long term effort. Annual fluctuations caused by weather are beyond our control and in the long run, the attitudes and actions of people toward turkeys will determine the success of habitat management.

224. Heichel, G. H., and Lester Hankin.
1977. Retention of particulate lead on foliage and twigs of a white pine windbreak. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 333-339.

The removal of particulate lead from the air by a 27-m-deep roadside windbreak of white pine containing eight rows of 25-year-old trees was studied. Knowledge of particulate trapping and retention was gained by atomic absorption spectrophotometry of the lead burden of foliage and twigs of various ages adjacent to and far from the road. The effectiveness of the windbreak was also shown by comparison of the lead content of the soil beneath the windbreak with that of an adjacent open, undisturbed field.

225. Heisler, Gordon M.
1977. Discussion of "Amelioration--How trees reduce energy loss in cities." Proc. Sci. Am. For. 1977: 67-70.

Trees have significant potential for reducing energy loss in cities--perhaps on the order of 1% of national energy consumption. At the mesoscale, the effect of trees on city temperatures and wind flow would determine the reduction in energy loss, but the effect of trees on citywide energy loss has not been quantified. By providing protection from sun and wind, trees definitely have great potential for reducing energy loss for individual buildings, particularly on relatively open sites. The upper limit for year-round energy saving by optimum placement of trees around individual buildings is probably about 25%. Proper arrangement of trees on building sites is important.

226. Heisler, Gordon M.
1977. Trees modify metropolitan climate and noise. J. Arboric. 3(11): 201-207, illus.

Human comfort in urban areas is altered by trees primarily through their influence on the exchange of radiant energy--both solar and long-wave. Although urban trees probably use large amounts of heat for transpiration, this process does not result in significantly cooler air in the vicinity of single trees or small groups of trees; even low winds quickly disperse the cooled air. Outdoor spaces that receive heavy pedestrian use should be made as versatile as possible by providing both sunny and shady sites for sitting and walking. Windbreaks may reduce energy requirements for heating buildings by 10 to 25%. Although shade obviously is a benefit in summer, winter shade is a disadvantage, and even deciduous trees create significant shade in winter. Trees are useful for noise control primarily because they scatter sound waves which are then absorbed by the ground. Dense forests or plantings of trees can reduce transmission of traffic noise, but if highways carrying high-speed truck traffic pass through residential areas, tree barriers alone cannot reduce sound levels to an acceptable level within about 350 feet of the highway.

227. Hendrix, William G.
1977. Visual land-use compatibility and scenic-resource quality. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 415-421.

The effect that land-use relationships have upon perceived quality of the visual landscape is discussed, and a case is made for expansion of fit-misfit theory into what has been called visual land-use compatibility. An assessment method that was designed to test people's perceptions of land-use relationships is presented and the results are discussed.

228. Herrick, Owen W.
1977. Impact of alternative timber management policies on availability of forest land in the Northeast. U.S. Dep. Agric. For. Serv. Res. Pap. NE-390. 14 p., illus.

Gaging the ability of the forest resource to satisfy future timber requirement is central to solving many problems arising from competition for use of forest land. In this study, production potentials of forest acreage in the Northeastern United States under management alternatives that range from extensive to intensive are weighed against several estimates of timber requirements for the year 2000. The different capabilities for fulfilling timber requirements in different parts of the region indicate areas likely to be affected most by further shifts toward nontimber use of forest land.

The intermediate option for forest management combines forest management at the present level with emphasis on harvesting the best timber-growing sites first. This option could meet timber requirements for year 2000 with roughly half the region's commercial forest area. Moreover, it could accommodate both intensive management and multiple-use objectives where they are most applicable by allowing flexibility in forest land-use decisions.

229. Herrington, Lee P., and C. Brock.
1977. Propagation of noise over and through a forest stand. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 226-228.

Measurements of the two-dimensional acoustic field in a forest resulting from a source located outside the forest indicated that the attenuation pattern near the ground is significantly different from the pattern higher up in the forest. The patterns of attenuation support the recent theory that the forest floor is the main absorber of acoustic energy in the forest.

230. Herrington, L. P., and Gordon M. Heisler.
1976. Conference on metropolitan physical environment: Vegetation, space, and structure for human amenities. Bull. Am. Meteorol. Soc. 57: 696-699.

Scientists and urban planners, designers and managers participated in a 5-day conference in Syracuse, New York, in August 1975. Urban micro- and mesoclimate,

outdoor acoustics, air quality, and "qualitative" aspects of the urban environment were discussed in 53 presentations. At least 20 presentations contained information about urban meteorology and climatology including volunteer weather-observation networks, surface-level temperatures, thermal structure of urban atmospheres, precipitation in urban areas, urban moisture, and urban microclimate. The Forest Service, State University of New York, and the American Meteorological Society sponsored the conference. Proceedings have been published in U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25.

231. Herrington, Lee P., and J. S. Vittum.
1977. Human thermal comfort in urban outdoor spaces. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 130-138.

Measurements of the physical environment of urban open spaces in Syracuse, New York, were used to compute the physiological responses of human users of the spaces. These calculations were then used to determine what environmental variables were both important to human comfort and susceptible to control by site design. Although air temperature and humidity are important to human thermal comfort, these variables were found not to be related in any way to site features; temperature and humidity in the central business district were uniform over space. The other variables found to be important to human thermal comfort are, in order of importance: solar radiation, infrared radiation, and wind speed. We found that all of these can be controlled to some extent by site design. Thus site design can be used to control human thermal comfort in outdoor urban spaces.

232. Hewlett, J. D., G. B. Cunningham, and C. A. Troendle.
1977. Predicting stormflow and peakflow from small basins in humid areas by the R-index method. Water Resour. Bull. 14: 231-254.

233. Hilt, Donald E.
1977. Introduction of black walnut and northern red oak seedlings in an upland hardwood forest in southeastern Ohio. U.S. Dep. Agric. For. Serv. Res. Note NE-241. 5 p., illus.

Black walnut and northern red oak seedlings were planted on a clearcut area in 1964. Three cultural treatments were applied to seedlings to control competing trees. Average height and survival were analyzed 13 growing seasons after planting. Results indicated that black walnut seedlings can be effectively established on good sites if cultural treatments are applied. Red oak seedlings are difficult to establish regardless of treatment or site.

234. Hilt, Donald E., and Donald W. Seegrist.
1977. RIDGE: A computer program for calculating ridge regression estimates. U.S. Dep. Agric. For. Serv. Res. Note NE-236. 7 p.

Least-squares coefficients for multiple-regression models may be unstable when the independent variables are highly correlated. Ridge regression is a biased estimation procedure that produces stable estimates of the coefficients. Ridge regression is discussed, and a computer program for calculating the ridge coefficients is presented.

235. Holt, Coleman.
1978. The effect of deer population on natural regeneration in the Allegheny Plateau region. Allegheny News, Soc. Am. For. p. 9.

236. Hornbeck, James W.
1977. Forests and water quality. In W. E. Sopper, J. A. Lynch, and E. S. Corbett, eds. Water resources at the forest-urban interface. U.S. Dep. Agric. For. Serv. Pinchot Inst. Environ. For. Res. PA-2. p. 11-13.

Water draining from essentially undisturbed forests usually represents a base line for high quality water.

This is due to the protection the forest cover provides against erosion and sedimentation, leaching of nutrients, and excessive heating of stream water by solar radiation. Man-made or natural disturbances can interrupt or eliminate this protection and cause forests to become non-point sources of water pollution. This paper reviews the pertinent literature and categorizes research needs.

237. Hornbeck, James W.
1977. Nutrients: A major consideration for intensive forest management. In Proc. Symp. Intensive Culture of Northern Forest Types. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-29: 241-250.

Estimates of nutrient losses from a stem-only harvest are compared with those from a whole-tree harvest of a clearcut northern hardwood stand. Combined nutrient losses due to increased leaching and removal of vegetation after stem-only harvesting are estimated to be 334 kg/ha for calcium and 265 kg/ha for nitrogen. For a whole-tree harvest, combined losses are estimated at 537 kg/ha for calcium and 486 kg/ha for nitrogen. Replenishment of available calcium and nitrogen could be a problem, depending upon the rates of soil mineralization and natural replacement.

238. Hornbeck, James W., Gene E. Likens, and John S. Eaton.
1977. Seasonal patterns in acidity of precipitation and their implications for forest stream ecosystems. Water, Air, and Soil Pollut. 7: 355-365. (Reprinted from Gen. Tech. Rep. NE-23, 1976.)

At the Hubbard Brook Experimental Forest in New Hampshire, the mean hydrogen ion content of precipitation ranges between 46 μeq/l in winter and 102 μeq/l in summer. As summer precipitation passes through the forest canopy, hydrogen ion concentrations are lowered by an average of 90 percent, primarily as a result of exchange with other cations.

239. Hornbeck, James W., and Robert S. Pierce.
1978. Acidity of rain and snow: a potential problem for New Hampshire. N.H. For. Notes 131: 6-7.

The Hubbard Brook studies have characterized the chemistry of precipitation falling on New Hampshire and have identified and defined some of the potential impacts. A major finding is that precipitation is acidic, largely as a result of human activities. The more obvious impacts, such as leaching of nutrients from foliage, have been determined, but many of the more subtle impacts will require further study.

240. Horsley, Stephen B.
1977. Allelopathic inhibition of black cherry by fern, grass, goldenrod, and aster. Can. J. For. Res. 7: 205-216, illus.

Small black cherry (Prunus serotina Ehrh.) seedlings grow slowly and soon die in low-density cherry-maple (Acer rubrum L.) orchard stands colonized by a dense ground cover of bracken fern (Pteridium aquilinum L.), wild oat grass (Danthonia compressa Aust.), goldenrod (Solidago rugusa Ait.), and flat-topped aster (Aster umbellatus Mill.). Studies of orchard stand persistence indicated allelopathic interference between black cherry seedlings and the herbaceous ground-cover plants. Foliage extracts of fern, goldenrod, and aster inhibited seed germination; aster foliage extract inhibited both shoot and root growth of seedlings growing on cotyledonary reserves; foliage extracts of fern, grass, goldenrod, and aster and root washings of goldenrod and aster inhibited shoot growth and dry weight accumulation of seedlings that had exhausted cotyledonary reserves. Soil from the upper horizons of an orchard stand did not moderate the toxicity of the herbaceous foliage extracts or root washings.

241. Horsley, Stephen B.
1977. Allelopathic interference among plants. II. Physiological modes of action. Proc. 4th North Am. For. Biol. Workshop. SUNY Coll. Environ. Sci. For., Syracuse. p. 93-136.

Few of the many allelopathic plant chemicals have been investigated; of these, terpenoids are the most important in arid and semiarid environments and phenolic compounds, especially the benzoic and cinnamic acids and coumarins, in temperate ecosystems. Most of these chemicals ultimately find their way into the soil, where they may be diminished and transformed. Much more research is needed.

242. Horsley, Stephen B.
1977. Woodland grasses, ferns, and club moss also have inhibitory allelopathic effect on black cherry. Can. J. For. Res. 7: 515-519.

On poorly drained Allegheny hardwood sites on the Allegheny Plateau of northwestern Pennsylvania and southwestern New York, hay-scented fern, New York fern, and short husk grass spread rapidly when stands are shelterwood cut to stimulate production of advance regeneration. Club moss does not spread rapidly, but is sometimes found in large patches. A comparison of paired field plots showed that the presence of any of these herbaceous species was correlated with reduced numbers of black cherry seedlings. In a greenhouse study, foliage extracts of hay-scented fern, New York fern, and short husk grass inhibited shoot growth of black cherry seedlings that had exhausted cotyledonary reserves.

243. Horsley, Stephen B.
1978. Allelopathic inhibition of forest regeneration. Allegheny News, Spring 1978. p. 12.

244. House, Michael C.
1977. Determination of relationships between climate, relief, species, and spoil material on tree development and soil formation at three locations in eastern Ohio. M.S. thesis. Ohio State Univ., Columbus.

245. Houston, D. R.
1977. Studies on Gonatorhodiella highlei, a mycoparasite of Nectria spp. associated with beech bark disease in England and North America. (Abstr.) Proc. Am. Phytopathol. Soc. 3: 306.

246. Houston, D. R.
1977. Protection against beech scale, Cryptococcus fagi, by Dichaena rugosa, a bark fungus of European and American Beech. (Abstr.) Proc. Am. Phytopathol. Soc. 3: 306.

247. Houston, D. R., and L. S. Dochinger.
1977. Effects of ambient air pollution on cone, seed, and pollen characteristics in eastern white and red pines. Environ. Pollut. 12: 1-5.

Assessments are lacking on the effects of continuous, ambient exposures of air pollution on the reproductive capabilities of forest trees. Significantly lower values were observed for white pine in polluted sites for number of seeds per cone, 100-seed weight, and percent pollen germination. In red pine, cone length, 100-seed weight, percent filled seed, percent seed germination, percent pollen germination, and pollen tube length were significantly lower in the polluted area. These findings suggest that sublethal concentrations of pollution may influence reproductive tissues of pines without causing visible foliage injury.

248. Houston, David R., and Harry T. Valentine.
1977. Comparing and predicting forest stand susceptibility to gypsy moth. Can. J. For. Res. 7: 447-461.

One hundred sixty-eight forest stands in the northeastern United States with different histories of defoliation and responses to defoliation by the gypsy moth were compared by principal components analysis (PCA) ordinations. The ordinations were based on tree structure feature variables. Tree mortality after defoliation often was greater in the resistant wet bottom and mesic slope and ridge stands than in the

susceptible dry ridge and sand stands. Our ordinations suggest that some stands, as a consequence of high oak mortality, may now be more resistant than before.

249. Hoy, M. A.
1976. Establishment of gypsy moth parasitoids in North America: An evaluation of possible reasons for establishment or non-establishment. In Perspectives in Forest Entomology. J. Anderson and H. Kaya, Editors. Academic Press, New York. Chapter 15, p. 215-232.

250. Hoy, Marjorie A.
1977. Rapid response to selection for a non-diapausing gypsy moth. Science 196(4297): 1462-1463, illus.

A multivoltine gypsy moth strain solves insectary production problems. It may also be a potential new tool for genetic control of the gypsy moth, yet it might have hazardous side effects. It will be useful for physiological and genetic comparisons with the normal diapausing gypsy moth.

251. Hoy, Marjorie A.
1978. Variability in diapause attributes of insects and mites: some evolutionary practical implications. In Proceedings in life sciences: Evolution of insect migration and diapause. (H. Dingle, Ed.) Springer Verlag, New York. p. 101-126.

252. Hoy, Marjorie A.
1978. Selection for a non-diapausing gypsy moth: some biological attributes of a new laboratory strain. Ann. Entomol. Soc. Am. 71: 75-80.

A non-diapausing strain of the gypsy moth, Lymantria dispar (L.) was selected within 8 generations. Larvae of the 6th generation of this strain (SEL) and larvae hatched from eggs field-collected in Pennsylvania were

compared with respect to adult morphology, egg mass size, pupal weight, developmental rate, sex ratio, and susceptibility to infection with nuclear polyhedrosis virus. Apanteles melanoscelus Ratzeburg, a braconid parasite of the gypsy moth, was reared on the non-diapausing SEL strain to determine the rate at which the parasite entered diapause under laboratory conditions. Selection of the non-diapausing strain proceeded under an 18-h daylength, even though the gypsy moth is thought to be photoperiodically neutral. Some SEL larvae reared from instar I to adulthood under an 8-h daylength produced egg masses that hatched promptly under the 8h conditions, indicating that genetic selection has not simply shifted the gypsy moth's critical photophase.

253. Hoy, Marjorie A., and Nancy F. Knop.
1978. Development, hatch dates, overwintering success, and spring emergence of a "nondiapausing" gypsy moth strain (Lepidoptera:Orgyiidae) in field cages. Can. Entomol. 110: 1003-1008.

Newly-hatched larvae from a selected (S) "non-diapausing" gypsy moth strain and larvae from field-collected wild (W) eggs were reared in field cages in Connecticut, U.S.A. beginning May 1976 to determine developmental rates and interbreeding potential. Reciprocal and inter se matings between S and W moths were monitored to determine if hatch occurred during the fall and if S and reciprocal $F_1$ hybrid (SW, WS) eggs could successfully overwinter and hatch at an appropriate time the following spring. S eggs did hatch in the fall. Survival of SW, WS, and some S eggs over the Connecticut winter demonstrated that this non-diapause colony is not suitable for a genetic control program in which the non-diapause trait is expected to act as a conditional lethal.

254. Hoyle, M. C.
1977. High resolution of peroxidase-indoleacetic acid oxidase isoenzymes from horseradish by ioselectric focusing. Plant Physiol. 60(5): 787-793.

255. Hoyle, Merrill C.
1977. High yield forestry from the tree's point of view. N.H. For. Notes 129: 27-28.

The problems that limit quality and growth for paper and yellow birch in New Hampshire's soil and climate are given in brief outlines. A prescription to overcome these problems is suggested. This is followed by results of an early field trial, which indicated that fast growth with very short rotations and high quality can be realized.

256. Hoyle, Merrill C.
1978. Illustrated handbook for high resolution of IAA oxidase-peroxidase isoenzymes by isoelectric focusing in slabs of polyacrylamide gel. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-37. 26 p., illus.

Specific techniques are presented for high resolution of peroxidase-IAA oxidase isoenzymes in polyacrylamide gel slabs by isoelectric focusing in pH gradients. Banding patterns are entirely reproducible. pH gradients are linear and there is no "cathode shift." The enzyme stains are very sensitive to low catalytic activity. Since the extreme cathodic or anodic isoenzymes of peroxidase-IAA oxidase enzyme have isoelectric points beyond the limits of wide range carrier ampholytes, it was necessary to adopt a more realistic definition of run time. Also, a labeling scheme similar to that used in electrophoresis was adapted for isoelectric focusing by use of a standard "marker isoenzyme." The number of peroxidase-IAA oxidase isoenzymes revealed by this technique is more than twice that previously reported.

257. Hoyle, M. C.
1978. Optimum conditions for indoleacetic acid oxidase extraction from Betula leaves. Plant Physiol. 42: 315-320.

258. Huff, F. A.
1977. Mesocale features of urban rainfall enhancement. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 18-25.

Analyses of data from the first four years of a 5-year research project at St. Louis indicate a substantial enhancement of summer rainfall downwind of the urban-industrial complex. This anomaly appears to be caused primarily by the intensification of naturally occurring storm systems through the addition of heat and raindrop nuclei from the urban area. Most of the enhancement is associated with organized storm systems and is most pronounced during and after the period of maximum diurnal heating.

259. Hutnik, R. J., and Grant Davis.
1978. Reclamation of coal mined land in the United States as compared with the Ruhr. In Gordon T. Goodman and Michael J. Chadwick, eds. Environmental management of mineral wastes. Sijthoff & Noordhoff, Alphen aan den Rijn, Netherlands. p. 71-83.

Reclamation practices in the United States differ from those in the Ruhr district of Germany mostly because of the differences in geography and in stage of development of mining laws. Mining in the United States is conducted over wide ranges of climate, physiology, and geology as contrasted to the rather homogeneous geographic area of the Ruhr. Surface mining, underground mining, and open-pit operations are found throughout the coal fields in the United States, cut underground mining is dominant in the Ruhr.

260. Janerette, Carol A.
1978. The effects of soak temperature on sugar maple seed germination. U.S. Dep. Agric. For. Serv. Res. Note NE-269. 2 p., illus.

The temperature at which sugar maple seeds were soaked before stratification significantly influenced their

germination. Maximal germination was obtained when seeds were soaked at 4°C, but if seeds were soaked at 25°C, germination decreased and the stratification requirement increased.

261. Janerette, Carol A.
1978. An in vitro study of seed dormancy in sugar maple. For. Sci. 24: 43-49, illus.

Organ culture techniques were applied to sugar maple seeds and seed parts in an attempt to locate the site of dormancy regulation. The study material included the complete embryo with the seed coat (testa) intact, with the seed coat removed, and with the seed coat and cotyledons removed. Results of this study suggest a two-phase dormancy mechanism--one phase controlled by the seed coat and the other controlled by the cotyledons. This study also indicated that the stratification process affects seed parts other than the embryonic axis.

262. Janerette, Carol A.
1978. A method of stimulating the germination of sugar maple seeds. Tree Planters' Notes 29(2): 7-8, illus.

The method used to stratify sugar maple seeds significantly influenced the time required to surpass 95% germination. When seeds were stratified in aluminum foil packets, 95% germinated within 18 days after the onset of germination, with current methods germination took 46 days to reach 95%.

263. Jennings, Daniel T., and Mark W. Houseweart.
1978. Sexing spruce budworm pupae. U.S. Dep. Agric. For. Serv. Res. Note NE-255. 2 p., illus.

Spruce budworm pupae can be sexed by the location and shape of the genital opening. The opening spans the 8th abdominal segment in the female pupae and is found on the 9th segment in male pupae.

264. Jennings, Daniel T., and Mark W. Houseweart.
1978. Spider preys on spruce budworm egg mass. Entomol. News 89(7 & 8): 183-186.

A penultimate male Metaphidippus flavipedes (G. & E. Peckham) (Araneae: Salticidae) was observed feeding on an egg mass of the eastern spruce budworm, Choristoneura funiferana (Clem.) (Lepidoptera: Tortricidae).

265. Jensen, Keith F.
1976. Air pollutants affect physiology of woody plants. In Proc. 4th North Am. For. Biol. Workshop. SUNY Coll. Environ. Sci. For., Syracuse. p. 47-55.

Air pollution is becoming an important environmental stress factor. It can cause foliar injury, reduce plant growth and interfere with many physiological processes, but its mechanism of action is not completely understood. One suggestion is that the pollutants react with cell membranes inside the leaves and change the ion balance in the cells. This in turn causes many secondary reactions, such as reduced enzyme activity or increased respiration. The foliar injury or growth change is the integrated result of all these secondary reactions.

266. Jensen, Keith F.
1977. Sulfur dioxide affects growth of forest tree species. (Abstr.) Proc. Am. Phytopathol. Soc. 4: 89.

267. Jensen, Keith F., and Frederick W. Bender.
1977. Seedling-size fumigation chambers. U.S. Dep. Agric. For. Serv. Res. Pap. NE-383. 4 p., illus.

The design of fumigation chambers is described. Each chamber has individual temperature, humidity, light, and pollutant control. Tenperature is variable from 15 to 35°C and controlled within ±1°C. Humidity is

variable from 25 to 95 percent and controlled within ±3 percent. Seedlings have been successfully grown in these chambers for up to 3 months.

268. Jensen, Keith F., and Leland F. Hanks.
1976. Growth analysis of poplar cuttings fumigated with $SO_2$. (Abstr.) Proc. Am. Phytopathol. Soc. 3: 306.

269. Jewell, Kevin E.
1978. Soil forming factors and yellow-poplar seedling growth on eastern Ohio minesoils. M.S. thesis. Ohio State Univ., Columbus.

270. Jordan, James S.
1977. Deer populations of the Allegheny National Forest, 1974-1977. In: A seminar on the problem of deer and forest regeneration: papers presented at 1977 summer meeting, Plateau and Northern Hardwood Chapter, Soc. Am. For., Ridgway, Pa. p. 40.

271. Joyner, Spencer A., Jr., Raymond S. Bradley, and Robert E. Reiter, Jr.
1977. Topoclimatic aspects of developmental suitability in the metropolitan landscape. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 163-171.

A computer-based procedure for geographically identifying, rating, and ranking topoclimatic characteristics is described. The influences of topography, land use, and soils are considered and combined into a single composite topoclimate developmental suitability map drawn by a Cal Comp plotter. By allocating development to the most suitable topoclimate areas, the long-term energy costs of maintaining human health and comfort could be minimized.

272. Kinerson, R. S., and I. Bartholomew.
1977. Biomass estimation equations and nutrient composition of white pine, white birch, red maple, and red oak in New Hampshire. N.H. Agric. Exp. Stn. Res. Pap. 62, 8 p.

273. Kingsley, Neal P.
1977. The forest resources of Vermont. U.S. Dep. Agric. For. Serv. Resour. Bull. NE-46. 58 p., illus.

A statistical and analytical report of the third forest survey of Vermont by the Forest Service. Statistical findings are based on the remeasurement of 1/5-acre plots and 10-point cluster plots. This report discusses and analyzes trends in forest-land area, timber volume, annual growth, and timber removals. Timber-products output by forest industries, based upon a canvass of industries in 1973, and the importance of timber and forests to the State's economy and environment are also discussed. The report also includes a discussion of the outlook for timber supplies during the next 30 years and forest-management opportunities in the state. Also included are 53 tables of statistical data.

274. Kingsley, Neal P., and Thomas W. Birch.
1977. The forest-land owners of New Hampshire and Vermont. U.S. Dep. Agric. For. Serv. Resour. Bull. NE-51. 47 p., illus.

A statistical-analytical report of a mail canvass of the owners of privately owned commercial forest land in New Hampshire and Vermont, based on responses to a mail questionnaire. The study was conducted in conjunction with forest surveys of the two states. Trends in forest-land ownership and the attitudes and intentions of owners regarding reasons for owning forest land, timber management, timber harvesting, and recreational use are discussed.

275. Kingsley, Neal P., and Douglas S. Powell.
1978. The forest resources of Kentucky. U.S. Dep. Agric. For. Serv. Resour. Bull. NE-54. 97 p., illus.

A statistical and analytical report on the third forest survey of Kentucky conducted in 1973, 1974, and 1975. Statistical findings are based on both remeasured and new 10-point cluster plots. The present status and trends in forest-land area, timber volume, and annual growth and removals are discussed. Timber-products output by forest industries, based upon a canvass of industries in 1974, and the importance of timber to the economy of the State also are discussed. The report includes a discussion of the outlook for timber supplies through 2004, and forest-management opportunities in the State. The status and importance of the nontimber forest resources of Kentucky are also discussed. Included are 75 tables of statistical data.

276. Kochenderfer, J. N.
1977. Area in skidroads, truck roads, and landings in the central Appalachians. J. For. 75: 507-508, illus.

In nine central Appalachian areas logged with wheeled skidders, there was 1 mile of road for every 19.8 acres; roads and landings occupied 10.3 percent of the area. In two areas logged with jammers, there was 1 mile of road for every 31.1 acres; roads and landings occupied 7.8 percent of the area.

277. Kochenderfer, J. N., and G. W. Wendel.
1978. Skyline harvesting in Appalachia. U.S. Dep. Agric. For. Serv. Res. Pap. NE-400. 9 p., illus.

The URUS, a small standing skyline system, was tested in the Appalachian Mountains of north-central West Virginia. Some problems encountered with this small, mobile system are discussed. From the results of this test and observation of skyline systems used in the western United States, the authors suggest some machine characteristics that would be desirable for use in the Appalachians.

278. Konheim, Arnold G.
1977. Community noise monitoring program. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 202-205.

There are numerous questions in regard to methods, instrumentation, and human and agency resources for community noise monitoring. The U.S. Environmental Protection Agency is currently in the process of seeking answers to these questions through research within the agency and by cooperation with other organizations, including the Department of Defense and the National Bureau of Standards. EPA hopes to have an acceptable protocol for community noise monitoring by July 1977, but there will still be a long-term need for more meaningful and efficient techniques.

279. Kopcewicz, J., and Z. Porazínski.
1976. Effect of blue light irradiation on metabolism of free and bound gibberellins in Scots pine (Pinus silvestris L.). Acta Univ. Nicolai Copernici, Biol. XVIII, Nauki Math.-Przyr. 37: 203-207,

Irradiation of 10-day-old Pinus silvestris seedlings with blue light for 36 hours greatly reduces the amount of bound gibberellins and increases the free gibberellins. The basis of these changes is not understood, but phytochrome is not necessarily involved. More research is needed to determine whether this can be developed into a useful treatment of seedlings.

280. Kopcewicz, J., Z. Zatorska, H. Kulikowska, and T. Szczésniek.
1977. Endogenous growth regulators in embryonic shoots of Scots pine at the time of male and female flower primordia initiation. Acta Soc. Bot. Pol. 56: 119-128.

The initiation of male strobiles in Pinus silvestris is correlated with a high content of gibberellins and a low level of auxins, the initiation of female

strobiles with the reverse condition. No direct correlation was found between the content of cytokinins or abscisic acid and the sex of early developing strobiles. More detailed studies are planned.

281. Koterba, Michael T., James W. Hornbeck, and Robert S. Pierce.
1977. Effects of sludge applications on soil water and vegetation in a northern hardwood forest in New England. Water Resour. Res. Cent., Univ. N.H., Res. Rep. 15, 23 p.

282. Krause, C. R., and K. F. Jensen.
1978. Microtopographical changes in hybrid poplar leaves associated with air pollution exposure. Scanning Electron Microsc. 2: 738, 755-757.

283. Krawczyszyn, J.
1977. Cambial domain pattern in the root and root collar of Platanus. Acta Soc. Bot. Pol. 46: 531-541.

Domains in Platanus roots migrate upward, producing interlocked grain similar to that in the stem. In the root collar region, however, the patterns become quite dynamic and the grain may remain straight in spite of great rebuilding activity among the cambial initial cells. Roots may influence stem domain patterns thus wood grain patterns in the bole.

284. Krawczyszyn, J.
1977. The transition from nonstoried to storied cambium in Fraxinus excelsior. I. The occurrence of radial anticlinal divisions. Can. J. Bot. 55: 3034-3041.

Anticlinal divisions in typical Fraxinus wood were classified on the basis of length of the anticlinal partition relative to the length of the dividing cell. Partitions were found to be relatively shorter in longer cells and vice versa. Thus short cells tended to divide radially and longer ones to divide

obliquely. Fraxinus is intermediate between the two basic type of cambium, storied and non-storied, and wood qualities might be altered by early cultural conditions that favor shifting the cambial type toward one or the other.

285. Lamson, N. I.
1978. Fertilization increases growth of sawlog-size yellow-poplar and red oak in West Virginia. U.S. Dep. Agric. For. Serv. Res. Pap. NE-403. 6 p., illus.

Sawlog-size even-aged hardwood stands in north-central West Virginia were fertilized with N, P, and K, singly and in combinations. Applications of N alone produced the largest increases in annual basal area growth of yellow-poplar, while P alone produced the largest increases in red oak. NP did not stimulate the growth of yellow-poplar more than did N alone and did not increase the growth of red oak more than did P alone. N increased the 7-year basal area growth of yellow-poplar 34 percent, and could be expected to increase the 7-year volume growth of pure stands of sawlog-size yellow-poplar by about 30 percent in this region.

286. Lamson, Neil I., and H. Clay Smith.
1978. Response to crop-tree release: sugar maple, red oak, black cherry, and yellow-poplar saplings in a 9-year-old stand. U.S. Dep. Agric. For. Serv. Res. Pap. NE-394. 8 p.

Crop trees were released in an Appalachian hardwood stand (site index 70 for northern red oak) that had been clearcut 9 years earlier. We released 134 yellow-poplar, red oak, black cherry, and sugar maple stems of seedling origin to a 5-foot radius around the bole of each study tree; 140 comparable stems were not released. These trees were dominant, codominant, or intermediate, and all treated trees were released to a dominant crown position. On the basis of results 5 years after treatment, we do not recommend releasing such trees by the methods used in this study.

287. Lancaster, Kenneth F., and William B. Leak.
1978. A silvicultural guide for white pine in the northeast. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-41. 13 p., illus.

This practical guide for managing eastern white pine points out special measures required to regenerate and to grow white pine. Treatments are prescribed for seedling and sapling, poletimber, and sawtimber stands. The effects of soil-site relationships are considered in preparing stand prescriptions.

288. Lanier, Gerald N., and Brian W. Burns.
1978. Barometric flux. Effects on the responsiveness of bark beetles to aggregation attractants. J. Chem. Ecol. 4: 139-147.

289. Lanier, G. N., W. E. Gore, G. T. Pearce, J. W. Peacock, and R. M. Silverstein.
1977. Response of the European elm bark beetle, Scolytus multistriatus (Coleoptera: Scolytidae) to isomers and components of its pheromone. J. Chem. Ecol. 3: 1-8.

The aggregation pheromone of the European elm bark beetle, Scolytus multistriatus, consists of 3 compounds: (-)-4-methyl--3-heptanol (I), (-)-α-multistriatin (II), and (-)-α-cubebene (III). Field tests demonstrated that a mixture of synthetic I and II plus III obtained from cubeb oil is attractive to both sexes of the beetle. Further laboratory and field tests have now determined the relative attractiveness of I, II, and III, their isomers, and various combinations of these compounds. Individually and in pairs the components are only slightly attractive; I + II is clearly the most active doublet. Indirect evidence indicates that only one of the four enantiomers of I is active. Of the 4 isomers of II, only α is active. These findings have an important bearing on the development of attractive baits for use in beetle suppression experiments.

290. LaPage, W. F.
1976. Public outdoor recreation: A policy wasteland. In Critical conservation choices: A bicentennial look. Proc. 31st Annu. Meet., Soil Conserv. Soc. Am. p. 183-188.

Most of society's "problems" in outdoor recreation are political issues: public versus private roles, fee levels for public lands, easy access versus primitive development, incentive programs for the private sector, etc. Policy analysis provides a perspective for analyzing society's outdoor recreation alternatives. Three areas of application are discussed: (1) Economic analysis of policy alternatives, (2) development of performance indicators for recreation delivery systems, and (3) methods of policy and program change. The author suggests the development of regional policy analysis centers staffed with Federal and State agency personnel, having the objectives of monitoring trends in supply and demand, using that data to analyze the probable outcomes of policy changes, and assisting State and local agencies through policy and program changes.

291. LaPage, W. F.
1977. New roles for government and industry in outdoor recreation. In South. States Recreation Res. Proc. Raleigh, N.C. p. 218-230.

Examination of future options for public park and recreation agencies is necessitated by the rising dominance of the private sector, the emerging public revolt against increased tax supported programs, and the trend toward greater public involvement in agency decision-making. A central role for public park and recreation agencies may be to cooperate with the private sector in such ways as joint development planning, increased use of concession-operated public facilities, and new directions for public park and recreation programs.

292. LaPage, W. F.
1977. Market analysis for recreation managers. In Outdoor recreation: Advances in application of economics. Proc. Natl. Symp. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. WO-2. p. 77-81.

One barrier to effective communication between economists and administrators in the field of outdoor recreation may be the word "demand." For the economist, "demand" is a concept of simple elegance and almost unlimited utility. For the recreation manager, "demand" is that less-than-elegant, but equally unlimited, horde knocking down the gate. This paper suggests that there is a middle ground--market analysis--where economic theory and the realities of administration can meet and where both economists and managers can find useful answers to their questions.

293. LaPage, Wilbur F.
1977. A plea for mediocrity in recreation research goals. Parks & Recreation 12(8): 25, 26, 50.

This paper critically examines past national recreation research efforts and argues for a system of national trend indicators to monitor the supply and demand for outdoor recreation services. In contrast to the almost total lack of government-sponsored indicator series in recreation, other facets of the economy such as public health and safety, education, housing, and employment are closely monitored by dozens of statistical series. Concludes with a plea that a substantial portion of Federal recreation research budgets be devoted to developing needed indicators of trends; and that "basic scientific" papers, lost in journals and of little use to public and private recreation planners, be correspondingly reduced.

294. LaPage, Wilbur F., and Paula L. Cormier.
1977. Images of camping--barriers to participation? J. Travel Res. 15(4): 21-25.

Images of camping's attraction and environment, reported by a nationwide sample of households in 1973, help

identify new market prospects and suggest marketing strategies. Across all regions of the country, heads of households under 30 report the most favorable images of camping. The best marketing prospects for major census regions are identified. And the need for reinforcement of specific image elements, such as "safe", "uncrowded", and "clean", are described for each of three major market segments - active campers, temporarily inactive campers, and prospective campers.

295. Lautenschlager, R. A., C. H. Kircher, and J. D. Podgwaite.
1977. Effect of nucleopolyhedrosis virus on selected mammalian predators of the gypsy moth. U.S. Dep. Agric. For. Serv. Res. Pap. NE-377. 6 p.

Nucleopolyhedrosis virus (NPV) of the gypsy moth was fed to three mammalian predators of the insect; the white-footed mouse, the short-tailed shrew, and the Virginia opossum. Analyses of general body condition, weight and reproductive efficiency, as well as necropsy and microscopic examination of tissues, indicated that the ingestion of NPV had no short-term effect on these animals.

296. Lautenschlager, R. A., and J. D. Podgwaite.
1977. Passage of infectious nuclear polyhedrosis virus through the alimentary tracts of two small mammal predators of the gypsy moth, Lymantria dispar L. Environ. Entomol. 6:737-738.

297. Lautenschlager, R. A., H. Rothenbacher, and J. D. Podgwaite.
1978. Response of small mammals to aerial applications of the nucleopolyhedrosis virus of the gypsy moth, Lymantria dispar. Environ. Entomol. 7:676-684.

Resident populations of white-footed mice, red-backed voles, opossums, chipmunks, and raccoons were evaluated

to detect short-term effects from aerial applications of the nucleopolyhedrosis virus (NPV) of the gypsy moth. NPV in 2 formulations was sprayed on woodland plots in central Pennsylvania at the rate of $2.5 \times 10^{12}$ polyhedral inclusion bodies (PIB)/ha. Comparisons of prespray and postspray censuses of white-footed mice and red-backed voles in control and treated plots revealed no changes in populations or body weight that could be attributed to NPV treatments. Data from 47 caged and 250 free-living mammals showed no significant differences in organ and tissue weights, hematological values or necropsy and histopathological rankings between control and treated mammals when sample sizes were large and mean total weight between groups similar.

298. Leak, W. B.
1977. Relationship of species and site index to habitat in the White Mountains of New Hampshire. U.S. Dep. Agric. For. Serv. Res. Pap. NE-397, 9 p.

299. Leak, William B.
1977. Review of Systems analysis IV. Ecology 58: 703-704.

A brief review of Systems Analysis and Simulation in Ecology, Volume IV, edited by Bernard C. Patten.

300. Leak. W. B.
1978. Relationship of species and site index to habitat in the White Mountains of New Hampshire. U.S. Dep. Agric. For. Serv. Res. Pap. NE-397. 9 p. illus.

Beech/sugar maple/yellow birch characterize successional stands on the fine tills and the enriched or cove sites. Washed fine till and coarse till are dominated during succession by beech and birch with some red maple. Red maple is abundant on sandy sediments, silty sediments, and dry compact till. Softwoods characterize successional stands on habitats with poor drainage, shallow rock, outwash, and wet compact till. Previous research

shows that coarse till, fine till, and enriched sites are the only habitats where pure hardwoods are the climax vegetation. Site index generally averages highest on habitats where hardwoods predominate.

301. Leak, William B.
1978. Relationships of forest vegetation to habitat on two types of glacial drift in New Hampshire. U.S. Dep. Agric. For. Serv. Res. Note NE-257. 5 p., illus.

Species composition and site index were determined on nine tree habitats in an area of schistose drift and compared with previous findings on habitats with granitic drift. Habitats on schistose drift supported more sugar maple and had somewhat higher site indexes. Compact tills in schistose drift supported northern hardwoods, and the site indexes for yellow birch were 66 to 71 feet. Compact tills in granitic drift supported softwood-hardwood mixtures and had a softwood climax; the site indexes for yellow birch were 56 to 57 feet. Species composition and site index for a given habitat may vary between glacial drifts with different mineralogies.

302. Leak, W. B., and S. M. Filip.
1977. Thirty-eight years of group selection in New England northern hardwoods. J. For. 75: 641-643, illus.

A 38-year period of group selection in northern hardwoods is resulting in a permanent composition of one-quarter to one-third intermediate and intolerant species. The diameter distribution follows the inverse J-shaped form that typifies uneven-aged stands. Uneven-age management based on a combination of group and single-tree selection appears to be silviculturally sound.

303. Leak, William B., and Stanley M. Filip.
1977. Uneven-aged management of northern hardwoods in New England. U.S. Dep. Agric, For. Serv. Inf. Leafl. NE-35. 8 p.

This brochure provides an introduction to uneven-age management for general audiences and practitioners. It describes (1) harvest-cutting methods including single-tree selection, group selection, and modifications; (2) growth and yield; and (3) logging methods and precautions.

304. Leonard, R. E.
1976. Design capacity: a possible approach to some backcountry management problems. Appalachia 42(2): 20-21.

Forest managers are concerned about the resource degradation occurring at backcountry recreation sites and would like to know what use levels a site can sustain without irreversible damage. A "design capacity" approach offers managers a system to help them determine optimum use levels. A site's capacity would depend on its physical condition, the social density expected by visitors, and the available site maintenance money. A spectrum of sites managed for different use levels should be provided.

305. Leonard, R. E., and S. C. Fay.
1978. A compost bin for handling privy wastes: its fabrication and use. U.S. Dep. Agric. For. Serv. Res. Note NE-254. 6 p., illus.

A 24-$ft^3$ (6.8-$m^3$) fiberglass bin was constructed and tested for its effectiveness in composting privy wastes. A mixture of ground hardwood bark and raw sewage was used for composting. Temperatures in excess of 60°C for 36 hours were produced in the bin by aerobic, thermophilic composting. This temperature is sufficient to destroy most pathogenic microorganisms. Composting in a leak-proof bin seems a safe, practical, and economical method of handling privy wastes.

306. Leonard, R. E., H. J. Plumley, and W. R. Holman.
1977. A design capacity system. In: Proc. Natl. Trails Symp., Lake Junaluska, N.C. Sep. 8-10. p. 160-163.

307. Leonard, R. E., and A. M. Whitney.
1977. Trail transect: A method for documenting trail changes. U.S. Dep. Agric. For. Serv. Res. Pap. NE-389. 8 p., illus.

A trail transect system that documents trail conditions and changes in trails has been used successfully over the past 3 years to measure soil loss and changes in trail width and vegetation. The system also can be used to study the relationship between trail degradation and the physical characteristics of a site. Data from trail transects can be useful in determining the physical conditions favorable for trail construction.

308. Lewis, F. B.
1978. Mixing and applying microbials. Proc. Workshop on Aerial Application of Insecticides Against Forest Defoliators. Columbus, Ohio. p. 25-29.

309. Lewis, F. B., and W. D. Rollinson.
1978. Effect of storage on the virulence of gypsy moth nucleopolyhedrosis inclusion bodies. J. Econ. Entomol. 71: 719-722, illus.

Nucleopolyhedrosis inclusion bodies of Lymantria dispar L. were stored as powders and as water suspensions under different conditions and for different lengths of time. PIB's were subjected to room and elevated temperatures, and to refrigeration and freezing. Suspensions retained their potency for 5 yr under refrigeration, and for 2 yr at room temperature. Air-dried powder at 4°C lasted for 1 yr before losing potency slowly. Air-dried powder and suspensions held at 38°C for 6 mo lost potency.

310. Likens, Gene E., F. Herbert Bormann, John S. Eaton, Robert S. Pierce, Noye M. Johnson.
1977. Hydrogen ion input to the Hubbard Brook Experimental Forest, New Hampshire, during the last decade. Water, Air, and Soil Pollut. 6: 435-445. (Reprinted from Gen. Tech. Rep. NE-23, 1976.)

311. Likens, G. E., F. H. Bormann, R. S. Pierce, W. A. Reiners.
1978. Recovery of a deforested ecosystem. Science 199(3): 492-496.

The well-known devegetated watershed on the Hubbard Brook Experimental Forest has been regrowing for more than 7 years. This paper discusses total nutrient losses and recovery of vegetation on both this watershed and a commercially clearcut watershed. Inability to quantify nitrogen fixation rates prevents prediction of nitrogen availability over a rotation. However, clearcutting over long rotations appears to be ecologically acceptable in the northeastern United States.

312. Likens, G. E., F. H. Bormann, R. S. Pierce, J. S. Eaton, and N. M. Johnson.
1977. Biogeochemistry of a forested ecosystem. Springer-Verlag New York, Inc. 146 p.

This book presents an in-depth analysis of the biogeochemistry of a northern hardwood forest ecosystem. It includes long-term data on precipitation and stream water quantity and chemistry. Annual, seasonal, and monthly variations in input-output budgets for many nutrient elements are given as well as nutrient cycles for calcium and sulfur--the two permanent ions. Comparisons are made between the ecosystem at Hubbard Brook and other forested ecosystems in the world.

313. Likens, G. E., and R. S. Pierce.
1976. Effects on aquatic systems. In Workshop Report on Acid Precipitation and the Forest Ecosystem. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-26. p. 8-10.

This report highlights the problems of acid precipitation on aquatic systems, as noted in the Symposium on Acid Precipitation and the Forest Ecosystem, and recommends four major research areas for future work to fill the present gaps. These include establishing permanent precipitation and stream monitoring networks, conducting comprehensive ecosystem studies, and use of experimental watersheds and lakes and streams.

314. Lima, W. P., J. H. Patric, and N. Holowaychuk.
1978. Natural reforestation reclaims a watershed: A case history from West Virginia. U.S. Dep. Agric. For. Serv. Res. Pap. NE-392. 7 p.

Thirteen years of hydrologic data from two contiguous small watersheds in West Virginia were analyzed to determine the effects on streamflow of natural reforestation on abandoned farmlands. From 1958 to 1970, streamflow on the watersheds was unchanged. The history of land use on the study area helps explain the apparent lack of hydrologic effects of reforestation. Long-term observation suggests that soil and water were protected adequately when the land became completely revegetated with any plant cover.

315. Linton, David.
1977. The battle of Whiskey Run. Parks & Recreation 12(9): 64-67, 92, 94., illus.

Streams are "recreational facilities," too. Saving one in a valuable strip of open space in one Pennsylvania community required petitions, bumper stickers, sympathetic media coverage, and a lot of work. But when the red tape had settled, the open space was preserved and the environment, politics, and people of the community had changed in the process.

316. Little, Silas.
1978. Fire effects in the New Jersey Pine Barrens. Frontiers 42(2): 29-32.

Fire effects in the Pine Barrens are modified by several factors: succession, differences in susceptibility among species and tree sizes, tree age, differences in heat among fires or parts of a fire, and frequency of fires. Differences in fire history are largely responsible for the great differences in forest composition--not only among the trees, but also among the non-arborescent plants.

317. Little, S., and I. F. Trew.
1976. Breeding and testing pitch X loblolly pine hybrids for the Northeast. Northeast. For. Tree Improv. Conf. Proc. 23: 71-85.

In 1964 the Northeastern Forest Experiment Station, in cooperation with Westvaco and many other organizations and individuals, established a breeding orchard of selected pitch and loblolly pine clones. Controlled pollinations were made between clones in 1968-74. Test plantings of 1-0 seedlings have been made in eight states. Initial results show that certain hybrids have good form, grow about as rapidly as loblolly pine and faster than pitch pine, and are hardy in some sections outside of loblolly pine's natural range.

318. Little, S., and I. F. Trew.
1977. Progress report on testing pitch X loblolly pine hybrids and on providing hybrid seed for mass plantings. Northeast. For. Tree Improv. Conf. Proc. 24: 14-28.

Recent test plantings of hybrids between selected clones of pitch and loblolly pines are briefly described, and results from some of the 1971-74 test plantings are discussed. Not only do certain hybrids combine loblolly pine's rate of growth and form with pitch pine's winter-hardiness, but their fibrous root systems apparently permit rapid growth on droughty sites or strip-mined areas. Hybrids in the early test plantings have so attracted the attention of practicing foresters that there is a demand for stock for mass plantings. This has forced decisions on procedures for supplying needed seed; the procedures, plans, and action are briefly described.

319. Lockmann, Ronald F.
1977. Man-made New Orleans: Some interactions between the physical and esthetic environments. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 355-367.

The relations between the physical environment and esthetic dimensions of the New Orleans cultural landscape are examined. The esthetic characterictics associated with New Orleans urban morphology are examined with respect to possible constraints by the physical environment. Salient townscape features such as street grid system, surface-drainage network, and

spatial features of selected residential neighborhoods provide instances that demonstrate the varying levels of physical environmental impingement upon the esthetic landscape.

320. Lynch. J. A., and E. S. Corbett.
1976. Implications of land management practices on water resources and the aquatic environment. Trans. Northeast. Soc. Conserv. Eng. p. 1-37.

Forest management practices are conducted on a variety of watersheds which include streams and impoundments of all sizes. In many cases headwater streams with fragile aquatic ecosystems are impacted. This paper discusses the physical and chemical basis of these impacts and associated management implications.

321. Lynch, J. A., E. S. Corbett, and R. Hoopes.
1977. Implications of forest management practices on the aquatic environment. Fisheries 2(2): 16-22.

Existing information was used to formulate the probable effects of timber harvesting on fisheries. These probable effects are evaluated on the basis that each species of fish has a particular set of environmental conditions and habitat preferences that are optimal for its maintenance. The effects of timber harvesting on the aquatic environment are analyzed in terms of (1) water temperature, (2) turbidity and sedimentation, (3) dissolved nutrients, (4) allochthonous organic detritus, and (5) streamflow.

322. Lynch, James A., James H. Patric, and Gerald M. Aubertin.
1977. Forests and water quantity. In Water resources at the forest urban interface, J. A. Lynch, and E. S. Corbett, eds. U.S. Dep. Agric. For. Serv. Pinchot Inst. Environ. For. Res. PA-2. p. 8-11.

Evaporative loss from forests can be managed crudely; usually it is reduced by timber harvest, and water

quantity (i.e., streamflow) is increased accordingly. The effects of other forest treatments such as type conversion, herbiciding, and reforestation are considered. It is concluded that present environmental concern precludes large-scale effort to increase water quantity by any of these treatments. Subjects for further research are suggested.

323. Lynch, J. A., W. E. Sopper, and E. S. Corbett.
1977. Timber harvesting and herbicide usage changed streamwater nutrients. Sci. in Agric., Pa. State Univ. 24(3): 8-9.

Clearcutting the lower 45 percent of a hardwood watershed in central Pennsylvania did not alter significantly the quality of water flowing from the watershed. However, when herbicides were applied to control regrowth of woody and herbaceous vegetation, significant changes in nutrient concentrations of streamwater were observed. Data are presented for calcium, magnesium, potassium, sodium, and nitrate-nitrogen.

324. Lynch, G. Robert, F. Daniel Vogt, and Harvey R. Smith.
1978. Seasonal study of spontaneous daily torpor in the white-footed mouse, Peromyscus leucopus. Physiol. Zool. 51: 289-299.

325. Lyon, Richard H., Christopher N. Blair, and Richard C. DeJong.
1977. Evaluating effects of vegetation on the acoustical environment by physical scale-modeling. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25: 218-225.

It is generally assumed that vegetation is beneficial acoustically, as well as esthetically, in that it may act as a shield to reduce highway noise impact on a community as in a sound absorber to reduce reverberant noise levels in city streets. Contradictory evidence exists, however, that noise may be increased because of vegetation. We performed field studies and laboratory scale-model experiments to study interaction

between sound-scattering by trees and shadowing by barriers. The studies indicate that, while barrier effectiveness may be reduced by addition of trees, propagation through a stand of trees may provide small noise reductions.

326. McCay, Roger E.
1978. Hiker preferences for trail features and maps. U.S. Dep. Agric. For. Serv. Res. Note NE-262. 4 p., illus.

Hikers at a Pennsylvania state park were asked what items were essential to their trail experience. From a list of 18 items, an overwhelming majority of hikers wanted to see trail names and directional signs along a natural-surfaced trail.

327. McCay, Roger E.
1978. Don't be a recreational slob. Pa. For. 68(3): 447-448.

Of about 200 landowners in Pike County, Pa., who were queried, more than half posted their land to keep out hunters, but other recreationists were also barred. Owners said recreationists trespass, tear down fences, litter, block driveways, leave gates open, shoot too close to buildings, don't compensate or even thank landowners, kill too much game, and overrun property. The author suggests ways recreationists could make themselves more welcome.

328. McGinnes, E. A., J. E. Phelps, P. S. Szopa, and A. L. Shigo.
1977. Wood anatomy after tree injury: A pictorial study. Res. Bull. 1025. Univ. Mo., Columbia. 35 p.

329. McLain, Thomas E., and George E. Stern.
1978. Withdrawal resistance of pallet nails and staples in five western woods. Va. Polytech. Inst. and State Univ., Wood Res. and Wood Constr. Lab., William H. Sardo, Jr. Pallet and Container Res. Lab. Bull. 155. 12 p., illus.

The delayed nail and staple withdrawal resistance was examined on the basis of 180 tests on pointless, helically threaded, hardened-steel, 3-inch by 0.120-inch pallet nails with umbrells heads; and 2-1/2-inch, 15-gauge, 7/16-inch crown, plastic-coated, pallet staples in pallet stock of five western species (Fremont cottonwood, California white and black oak, Oregon white oak, and coast-type Douglas fir.) The fastener effectiveness in these species was compared with that in other wood species.

330. McManus, M. L.
1976. Weather influences on insect populations. In Proc. 4th Natl. Conf. Fire and For. Meteorol. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. RM-32. p. 94-100.

Weather influences forest insect populations in many ways, some more obvious than others. The indirect effect of weather operating through the host plant may be more critical to the survival of individuals than the direct effect of specific components of weather. Examples are presented that demonstrate how weather affects forest insect populations and various approaches are discussed.

331. McManus, Michael L.
1978. Expanded gypsy moth research and development program. J. For. 76: 144-149, illus.

Since it was introduced into New England in 1869, the gypsy moth, Lymantria dispar L., has slowly spread through the oak-hickory forests to the south and west and continues to be the most serious forest insect problem in the East. Work on the moth was increased substantially in 1971 to cope with a region-wide outbreak in the Northeast, and in 1975 it was accelerated through the USDA Combined Forest Pest Research and Development Program. New technology from the program is being incorporated into an integrated system for managing this insect.

332. McTaggart-Cowan, J. D., and J. W. S. Young.
1977. Surface air temperature in a maritime metropolitan region. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 88-93.

In investigations of the micrometeorology of any area, one of the basic parameters required is the spatial and temporal distribution of the surface air temperature. A mobile instrument mounted on an automobile was used for measuring temperatures within the surface mixed layer. Details are presented of a case study at Saint John, New Brunswick, in summer. The effects of topography, lakes, sea-breezes, and land-use are discussed.

333. Mader, D. L., H. W. Lull, and E. I. Swenson.
1977. Humus accumulation in hardwood stands in the Northeast. Bull. 648. Mass. Agric. Exp. Stn., Amherst, and Northeast. For. Exp. Stn. 37 p.

Humus layers were sampled in six regions in the Northeast according to stand class and soil drainage class, a total of 209 plots. The average depth, weight, organic matter content, and moisture-holding capacity of the layers are presented by regions, stand class, soil drainage class, and overall average. The relationships of humus accumulation to drainage class, dbh, height age, basal area, site index, plot position, elevation, slope, and aspect were investigated by simple and multiple regression analyses. Age and drainage class were important determinants of amount and type of humus accumulation. Hydrologic importance of the humus layers is evaluated.

334. Marchand, Peter J.
1977. Subalpine bogs of the Mahoosuc Range, Maine: Physical characteristics and vegetation development. Cent. North. Stud., Wolcutt, Vt. 19 p.

335. Marquis, David A.
1977. The role of tree improvement in the Northeast: A silviculturist's point of view. Northeast. For. Tree Improv. Conf. Proc. 25: 48-57.

The role of tree improvement in the Northeast is likely to be quite different from that in other parts of the country, because artificial regeneration is not widely used on the commercial forest lands of this region. The best opportunities for traditional planting and improvement programs seem to be in using coniferous species such as eastern white pine for the reforestation of open or poorly stocked lands, or forestation of open or poorly stocked lands, or for conversion from poor-quality hardwoods on appropriate sites. In the mixed hardwood stands that predominate throughout the Northeast, the widespread use of artificial regeneration and tree improvement will probably include mixtures of natural and artificial regeneration in the same stand. Imaginative and coordinated efforts by geneticists and silviculturists will be required to make such a culture feasible.

336. Marquis, David A.
1977. Impact of deer on Allegheny hardwood regeneration. In: A seminar on the problem of deer and forest regeneration: papers presented at 1977 summer meeting, Plateau and Northern Hardwood Chapter, Soc. Am. For., Ridgway, Pa. p. 28.

337. Marquis, David A.
1977. Devices to protect seedlings from deer browsing. U.S. Dep. Agric. For. Serv. Res. Note NE-243. 7 p., illus.

Studies on the Allegheny Plateau of Pennsylvania have shown that several types of wire or plastic tubes can be erected around tree seedlings to protect them from deer browsing. The two most promising devices are a 4- to 6-inch diameter plastic tube with small mesh and a 12-inch diameter tube constructed of chicken wire. Both types need to be at least 5 feet tall to provide adequate protection in areas of heavy browsing

pressure. The plastic protectors are more expensive than those made of wire, but take somewhat less time to make, and offer added protection from rodents.

338. Marquis, D. A.
1977. Application of uneven-aged silviculture and management on public and private lands. Proc. In-Service Workshop on Uneven-aged Silviculture and Management in the Western United States, Redding, Calif. 1976. p. 20-54.

Guidelines for application of uneven-aged silviculture are scattered and fragmented. Information on choice of cutting method, regulation of yield, marking, allowable cut projections, road layout, and control of residual tree damage are summarized in this paper.

339. Martin, Frank P., and Grace L. Powell.
1977. The urban heat island in Akron, Ohio. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 94-97.

Data gathered by automobile traverse were used to describe the urban heat of Akron, Ohio. Observations were made at 2100 or 2200 EST on four nights--17 April, 11 July, 10 October, and 2 January. Weather conditions not conducive to heat-island development were avoided. Temperatures in the center of the heat island were 6 to 14° warmer than rural areas outside the city. The heat-island center was always over a mixed residential/commercial area. Topographic influences were apparent in the heat-island pattern.

340. Martin, A. Jeff.
1977. A computer program for analyzing PERT networks. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-32. 10 p., illus.

A computer program designed to analyze PERT networks is described. Use of the program is illustrated with an example of a National Forest timber sale. A source listing of the program, input instructions, output from the example, and an explanation of the output tables are included.

341. Martin, A. Jeff.
1977. Increased yields from near-complete multi-product harvesting of a cove hardwood stand. North. Logger 26(4): 6-7, 37.

A 1.7-acre yellow-poplar/red maple stand in southwest Virginia was cruised and the timber harvested for sawlogs and whole-tree chips. Cruise data were used to estimate yields from four other roundwood harvesting options. The actual yield from near-complete harvesting exceeded the estimated yields from the four roundwood options by 27 to 104 percent.

342. Martin, C. Wayne.
1977. Distribution of tree species in an undisturbed northern hardwood-spruce-fir forest, the Bowl, N.H. U.S. Dep. Agric. For. Serv. Res. Note NE-244. 6 p., illus.

Knowledge acquired from forests that have never been logged can provide clues to the long-term effects of resource utilization. In 1974, a survey was made of the vegetation of the Bowl Research Natural Area in central New Hampshire, known to be undisturbed by humans; and an adjacent watershed known to have been logged in the late 1880's. There were no significant differences in the mean basal areas and aboveground biomass of trees between the two watersheds, indicating that 90 years after logging this forest has nearly recovered. The major species in the Bowl are yellow birch, beech, sugar maple, red spruce, and balsam fir. The forest has a mean basal area of 28 $m^2$/ha and contains about 260 metric tons of aboveground dry biomass. A nearby 60-year-old second growth forest contains about 23 $m^2$/ha basal area and only about 140 t/ha.

343. Matlack, Martin C., and Daniel T. Jennings.
1977. Cohabitation of female spiders guarding egg sacs. J. Kans. Entomol. Soc. 50: 519-522.

344. Mazzone, H. M., and G. H. Tignor.
1976. Insect viruses: Serological relationships. In Advances in Virus Research 20: 237-270.

The subject of this review is the serological characterization of insect pathogenic viruses from the following five pathogenic and morphologic groups: nucleopolyhedrosis viruses, granulosis viruses, cytoplasmic polyhedrosis viruses, pox-like viruses and the nonoccluded group that includes the iridescent viruses. The subject matter discussed includes terminology, techniques, immunofluorescence and pathogenesis, antigenic characterization and serologic relationships, serology in adaption, latency, and synergism, reactions between viral components and host material, insect viruses as biological control agents: serologic aspects, and the use of computers in insect virus serology.

345. Meadows, J. C., Jr., and A. T. Schuler.
1977. Nonlinear programing and the decreasing marginal utility problem: A goal programing framework for decision. Inst. Manage. Sci. Proc. 1976: 307-314.

Previously used goal programing approaches to multiple-use-management decision-making incur two serious drawbacks: they do not tackle the decreasing marginal utility problem; and the preemptive weights are too strong an assumption. This paper describes a theoretical attempt to solve these problems via nonlinear goal programing methods.

346. Melhuish, John H., Jr.
1977. Total fatty acid profiles of several closely related fungi. (Abstr.) Proc. 3rd North Am. Conf. on Mycorrhizae. Athens, Ga. 1977. p. 93.

347. Mendel, Joseph J., and Margaret K. Peirsol.
1977. Quality index tables for some eastern hardwood species based on lumber prices from 1970 to 1974. U.S. Dep. Agric. For. Serv. Res. Pap. NE-370. 10 p.

Revised quality index (QI) tables for white ash, beech, black cherry, birch, hard maple, soft maple, red oak, white oak, and yellow-poplar are based on 1970-74 lumber prices for the Appalachian and northeastern marketing areas. Changes in QI since 1964-68 were greatest for white oak; there also were significant changes in QI for red oak, white ash, and yellow-poplar.

348. Merrow, Susan B., Robert Clarke, and Paul E. Sendak. 1977. How does it taste? Natl. Maple Syrup Dig. 16(3): 11-13.

349. Meyerson, Norman L. 1977. Study of traffic noise levels at various heights of a 39-story building. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 195-201.

Comparative measurements of exterior noise levels made at floors 3, 14, 26, and 37 of a high-rise apartment tower, when presented as a statistical distribution of percent exceedance vs. decibels, show the nature of the influence of local traffic at the low floors compared to the influence of an area source at the high floors. The open window penalty to interior noise levels was measured as well as the side street noise propagation along the building from avenue vehicular traffic sources alone.

350. Michalski, L. 1976. Effects of ionizing radiation on changes in the level of gibberellin-like substances during Scotch pine seed germination. Acta. Soc. Bot. Polon. 45: 263-269.

Gamma-irradiated pine seeds have a higher ratio of free to bound gibberellins than do controls. Exposure of seeds to 1.0 kR of gamma irradiation for 24 hours increases the level of free gibberellins whereas the level of bound gibberellins decreases. Perhaps ionizing radiation releases bound gibberellins that may influence later growth.

351. Miller, D. R.
1977. UCONN Studies of plant-atmosphere relationships may lead to improved land use in Connecticut. Res. for Conn. 47. Storrs Agric. Exp. Stn., Storrs, Conn.

352. Miller, David R.
1977. Structure of the microclimate at a woodland/parking-lot interface. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 109-114.

Radiation balances and vertical and horizontal profiles of air temperature, vapor pressure and wind speed were measured across the interface of a large asphalt parking lot and an 18-m-tall Quercus velutina forest. The partitioning of available energy over the adjacent areas shows steep gradients between the parking lot and forest microclimates. Horizontal temperature and humidity gradients across the interface were of the same order of magnitude as the vertical gradients above the respective surfaces.

353. Miller, D. R., and C. A. Federer
1976. Sap velocity, atmospheric demand, and transpiration in paper birch and white oak saplings. (Abstr.) Bull. Am. Meteorol. Soc. 57: 1407.

354. Miller, Robert W., Robert S. Bond, and Brian R. Payne.
1978. Land and timber values in an urban region. J. For. 76: 165-166.

355. Miller-Jones, D. N., D. R. Houston, and T. F. Preece.
1977. The use of electrical resistance measurements to detect watermark disease of cricket bat willow. Plant Dis. Rep. 61: 268-272.

One of the symptons of watermark disease of cricket bat willow, Salix alba var. caerulea, caused by the bacterium Erwinia salicin, is a physical weakening and discoloration of the wood, rendering it useless

for cricket bat manufacture. Diseased trees, which must be destroyed by burning, often escape detection until they are harvested. Watermark-discolored tissues were readily distinguishable from healthy xylem, and from tissues discolored from other causes, by their low resistance to a pulsed electric current. Disease was detected in trees and propagating shoots with no apparent external symptoms.

356. Millner, James D.
1977. Credit for maple producers. Natl. Maple Syrup Dig. 16(3): 17-23.

General procedure and required information for applying for a loan for a maple syrup business are presented. Four sources of credit are discussed--commercial banks, Farmers Home Administration, Farm Credit Service, and Small Business Administration.

357. Mitchell, Thomas R., and David P. Worley.
1976. Land taxation changes affect woodland management objectives. Ohio Woodlands 14(4): 6-7.

Property taxes alone can equal or exceed net future values expected from growing timber from bare land. Hence they discourage both ownership and management for timber production per se. Either owners must recognize multiple benefits from forest-land or taxing arrangements that encourage timber production must be enacted.

358. Moeller, George H.
1977. The Pinchot Institute: Toward managing our urban forest resources. J. Arboric. 3(10): 181-186.

In 1971, the Forest Service established the Pinchot Institute of Environmental Forestry Research to deal with forest-related environmental concerns in urban areas. The Institute is named in honor of the first Chief of the Forest Service, one of America's foremost early conservationists. Within the Pinchot Institute, the Forest Service and nine northeastern universities

have joined together to form the Consortium for Environmental Forestry Studies. Through this program, scientists at institutions throughout the Northeast are developing information needed to solve problems of policy formulation, regional planning, and management of urban forest resources. Though the research is done in the Northeast, much of it is applicable to management of urban forests throughout the Nation and abroad. By coordinating Forest Service research with that of other Consortium members, the Institute seeks to determine how trees and forests can best serve the needs of urban man.

359. Moeller, George H.
1977. The Pinchot Institute--A program for urban forestry research. In Proc. Tree Wardens, Arborists Util. Conf. p. 87-94.

At the outset of environmental consciousness in the Seventies, the Forest Service established a special research institute to deal with forest-related environmental concerns in urban areas. It is named the Pinchot Institute of Environmental Forestry Research, in honor of the first Chief of the Forest Service; one of America's foremost early conservationists. Within the Pinchot Institute, the Forest Service and nine northeastern universities have joined together to form the Consortium for Environmental Forestry Studies. Through this program, scientists are developing the information needed to solve problems of policy formulation, regional planning, and management of urban forest resources. The Forest Service's own research and the research of other Consortium members is coordinated to meet the Institute's overall objective--to determine how trees and forests can best serve the needs of urban man.

360. Moeller, George H.
1977. Research priorities in environmental education. In Children, Nature, and the Urban Environment: Proc. Symp. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-30. p. 219-222, illus.

Although natural processes operate in urban areas, they are difficult to observe. Much discussion during the

symposium-fair was devoted to finding ways to improve urban children's environmental understanding through environmental education programs. But before effective environmental education programs can be developed, research is needed to: test the effectiveness of various approaches to teaching environmental education in relation to differences among children; help define testable program goals that relate to a child's level of comprehension; develop better methods of training teachers and administering environmental education programs; and identify ways to use elements found in the urban environment to foster an understanding of environmental concepts.

361. Moeller, G., and T. More.
1976. Future demands of urban residents for U.S. National Parks and Forests. In Trees and Forests for Human Settlements: Proc. XVIth IUFRO World Congr. Toronto, Canada. Centre for Urban Forestry Studies, Univ. Toronto. p. 93-106.

362. Moeller, George H., Elwood L. Shafer, and Russell L. Getty.
1977. Leisure environments of tomorrow. In Outdoor recreation: Advances in application of economics. Proc. Natl. Symp. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. WO-2: 22-34, illus.

As an aid to policy and decisionmaking about future environmental problems, a panel of experts was asked to predict the probabilities of future events associated with natural resource management, wildland-recreation management, environmental pollution, population-workforce-leisure, and urban environment. Though some of the predictions projected to the year 2050 may sound fantastic now, the authors think that some of the events predicted may occur even sooner than forecast.

363. Montgomery, Michael E., and Lowell R. Nault.
1977. Comparative response of aphids to the alarm pheromone, (E)-β-farnesene. Entomol. Exp. & Appl. 22: 236-242.

364. Montgomery, Michael E., and Lowell R. Nault.
1977. Aphid alarm pheromones: Dispersion of *Hyadaphis erysimi* and *Myzus persicae*. Ann. Entomol. Soc. Am. 70: 669-672.

365. Montgomery, Michael E., and David G. Nielsen.
1978. Dips for control of black vine weevil larvae in pots. Insecticide and Acaricide Tests 3: 161.

366. More, Thomas A.
1977. An analysis of wildlife in children's stories. *In* Children, Nature, and the Urban Environment: Proc. Symp. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-30. p. 89-92.

Urban people encounter wildlife in various ways. One of the most important is the vicarious encounter with animals in children's stories. The surprising number of children's animal stories can be divided into three categories, each of which affects children's beliefs, attitudes, and preferences for wildlife. Because children's stories may have such a lasting effect, we need to consider the ways in which animals are portrayed in them.

367. More, Thomas A., Robert O. Brush, and J. Alan Wagar.
1977. Variation and recreation quality in river management. *In* Proc. River Recreation Manage. and Res. Symp. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-28. p. 329-333.

Variation in the river environment is a major determinant of the quality of river recreation experiences. In river canoeing, there are four main sources of variation: psychosocial variation, landscape variation, river variation, and variation inherent in the activity itself. By considering how these sources of variation interact, it should be possible to affect the quality of the recreation experience and accomplish other management objectives as well.

368. More, Thomas A., and Brian R. Payne.
1978. Affective responses to natural areas near cities. J. Leisure Res. 10(1): 7-12.

In an exploratory study of emotions in recreation, visitors to three Audubon nature centers in Massachusetts completed a questionnaire to measure their moods at the beginning and at the end of their on-site visits. Entering levels of negatively valued moods were quite low, and decreased significantly during the visit. Entering levels of positively valued moods were moderately high, but these also decreased slightly during the visit. The moods of the visitors appeared to be unrelated to background characteristics. To account for these findings, a process emphasizing anticipation is postulated, and areas for future research are suggested.

369. Moss, Michael R.
1977. Sulfur pollution: An environmental study of Welland, Ontario. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 308-314.

The distribution of sulfur as an environmental pollutant is analyzed in the vicinity of Welland, Ontario. A biogeochemical-cycle approach enables areas of excess accumulation to be compared among all linked ecosystem components. Although the patterns of distribution are similar, the amounts of sulfur accumulated in different ecosystems, grassland and woodland, show marked contrasts. The significance of these findings to urban and rural land-use planning is considered.

370. Mott, D. G.
1976. The consequences of applying no control to epidemic spruce budworm in eastern spruce-fir. In Proc. Symp. Spruce Budworm. U.S. Dep. Agric. For. Serv. Misc. Publ. 1327: 67-72.

371. Murphy, C. E., Jr., T. R. Sinclair, and K. R. Knoerr. 1977. A model for estimating air-pollutant uptake by forests: Calculation of absorption of sulfur dioxide from dispersed sources. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 340-350.

The computer model presented in this paper is designed to estimate the uptake of air pollutants by forests. The model utilizes submodels to describe atmospheric diffusion immediately above and within the canopy, and into the sink areas within or on the trees. The program implementing the model is general and can be used with only minor changes for any gaseous pollutant. To illustrate the utility of the model, estimates are made of the sink strength of forests for sulfur dioxide. The results agree with experimentally derived estimates of sulfur dioxide uptake by crops and forest trees.

372. Myklestad, Erik, and J. Alan Wagar. 1977. PREVIEW: Computer assistance for visual management of forested landscapes. Landscape Plann. 4: 313-331.

The PREVIEW computer program facilities visual management of forested landscapes by generating perspective drawings that show proposed timber harvesting and regrowth throughout a rotation. Drawings show how changes would appear from selected viewing points and show landscapes as either a grid of distorted squares or by symbols representing trees, clearings, water, rock, etc. PREVIEW can also show roads and other linear features.

373. Nathan, K., G. H. Nieswand, E. S. Corbett, and J. R. Pawlow. 1976. Rainfall-runoff relationship of a small drainage area under suburban development. Am. Soc. Agric. Eng. Winter Meet., Chicago, Ill. Pap. No. 76-2542, 25 p.

A 10-year study of a small watershed showed a 41 percent increase in the peak flow of a 1-hour unit hydrograph, resulting from a 4.19 percent decrease in

natural vegetation. Runoff volume of a 10-year, 1-hour storm increased 36 percent with an increase in peak runoff rate of 70 percent.

374. Nault, L. R., and M. E. Montgomery.
1977. Aphid pheromones. In: Aphids as virus vectors. Academic Press, Inc., New York. Chap. 22.

375. Nielsen, David G., and Michael E. Montgomery.
1977. Toxicity and persistence of foliar insect sprays against black vine weevil adults. J. Econ. Entomol. 70(4): 510-512.

376. Nielsen, D. G., L. E. Terrell, and T. C. Weidensaul.
1977. Phytotoxicity of ozone and sulfur dioxide to laboratory fumigated Scotch pine. Plant Dis. Rep. 61: 699-703.

377. Nieswand, G. H., T. Shelton, T. Fusillo, and E. S. Corbett.
1976. A study of the impact of suburban development on water quality in a small watershed. Am. Soc. Agric. Eng. Winter Meet., Chicago, Ill. Pap. No. 76-2543, 18 p.

Preliminary results of a study of the impact of suburban development on water quality in a small watershed are presented. With approximately 35 percent of the watershed developed or under construction, some changes in baseflow water quality have been observed. Greater changes in water quality occurred between baseflow and stormflow conditions during the study period. Mean loadings of all observed water quality parameters were considerably higher during stormflows than during baseflows. Water quality changes during stormflows may be a more valid indication of the impact of development than baseflows.

378. Nishino, C., W. S. Bowers, M. E. Montgomery, L. R. Nault, and M. W. Nielson.
1977. Alarm pheromone of the spotted alfalfa aphid, Therioaphis maculata Buckton (Homoptera: Aphididae) J. Chem. Ecol. 3(3): 347-357.

379. Nolley, Jean W.
1977. Christmas trees: a bibliography. Am. Christmas Tree J. 21(2): 9-11.

1977 supplemental listing of published information on the Christmas tree industry.

380. Nolley, Jean W.
1978. Christmas trees: a bibliography (1978 Supplement) Am. Christmas Tree J. 22(1): 27-28.

381. Normand, Joelee.
1977. Techniques of data analysis and presentation for planners of the metropolitan environment. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 438-447.

Relationships between the characteristics of the physical environment of a metropolitan area and the acitivites of its human inhabitants can be used to predict probable future dynamic trends, both demographic and environmental. Using simple linear regression, we were able to highlight several dynamic features of the metropolitan area of Tulsa, Oklahoma. Computer movies of the growth of Tulsa and attendant air-pollution problems were used for showing demographic and physical features simultaneously to facilitate the information-assimilation process so critical to planning.

382. Northeastern Forest Experiment Station.
1977. How to prepare manuscripts for Station publication: A desk guide for authors and typists. U.S. Dep. Agric. For. Serv. Northeast. For. Exp. Stn. (unnumbered).

383. Northeastern Forest Experiment Station.
1977. Proceedings of the Conference on Metropolitan Physical Environment. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. 447 p.

384. Northeastern Forest Experiment Station.
1977. Proceedings of the Symposium on Intensive Culture of Northern Forest Types. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-29. 356 p.

A report on the symposium held in July 1976 at the University of Maine, Orono, containing 35 papers presented at the meeting.

385. Northeastern Forest Experiment Station.
1977. Children, nature, and the urban environment: Proceedings of a symposium-fair. U.S. Dep. Agric. For. Serv. Gen. Tech Rep. NE-30. 261 p., illus.

A report on the symposium-fair held 19-23 May, 1975 at the C. H. Marvin Center, the George Washington University, Washington, D.C., containing 33 papers. Sections are devoted to defining the role of natural environments, human development research on urban children and the natural environment, and community and institutional response to fostering desirable relationships between nature and development of urban children.

386. Northeastern Forest Experiment Station.
1977. 1976 at the Northeastern Forest Experiment Station. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-33. 40 p.

A summary report on highlights of research activities and accomplishments of the Experiment Station in 1976, including an annotated list of publications.

387. Nyland, Ralph D., Donald F. Behrend, Phillip J. Craul, and Herbert E. Echelberger.
1977. Effects of logging in northern hardwood forests. Tappi 60(6): 58-61.

Timber was harvested at three locations using individual tree selection, strip clearcutting, and patch clearcutting. Special practices did not significantly reduce injuries to residual trees. Logging reduced the distribution and density of regeneration. Skidding affected 16-18% of the soil surface within partial cuts and about twice that in clearcuts due to more minor disturbance. Erodibility appeared limited. Songbird numbers and diversity increased. Effects upon other animals were unclear. Time devoted to various jobs was similar between methods. Top-lopping and sapling felling reduced output significantly. Cutting method and top-lopping appeared less visually important than group affiliation, although lopped partial cuts were most preferred. Viewers disliked logging slash in all treatments. No method had significant detrimental effects upon the forest and associated resources.

388. Odell, Thomas M.
1978. Periodicity of eclosion and pre-mating behavior of gypsy moth. Ann. Entomol. Soc. Am. 71: 748-751, illus.

The eclosion and pre-mating behavior of 288 male and 450 female gypsy moth, Lymantria dispar (L.), adults were observed during July 22-29, 1972. Eclosion activity of both sexes was strictly diurnal; initial daily eclosion was synchronized with sunrise. The periodicity of peak eclosion differed from day to day, and appeared to be influenced by temperature variation; temperatures above 24° C apparently enhanced eclosion. The average time from eclosion to first flight in males was 3.56± 0.12 h. Nocturnal flight occurred at temperatures above 21° C.

389. Paproski, Dennis M., and Julian R. Walker.
1977. A first-approximation-urban-air-quality indicator. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 254-262.

Development of the first-approximation-urban-air-quality indicator was reported by the Economic Council of Canada. The indicator takes account of ambient

concentrations of five pollutants: sulfur dioxide, particulate matter, oxides of nitrogen, carbon monoxide, and total oxidants. Epidemiological evidence indicating the potential impact of these pollutants on human health is also reported. Values of the indicator are calculated for the years 1971-74 for a number of Canadian cities: the overall trend appears to be toward cleaner air, though concentrations of oxidants and nitrogen oxides have increased.

390. Parker, J.
1976. Effects of defoliation on levels of chlorogenic acid in oak bark. Plant Physiol. Suppl. 57: 64.

391. Parker, Johnson.
1978. Effects of fertilization on shoot growth of defoliated and undefoliated red oak seedlings. U.S. Dep. Agric. For. Serv. Res. Pap. NE-399. 3 p., illus.

Defoliated Quercus rubra seedlings treated with dry or liquid + dry fertilizer grew more than unfertilized, undefoliated seedlings.

392. Parker, Johnson.
1978. Free sugars and polyols in developing birch leaves. (Abstr.) Plant Physiol. Suppl. 61: 9.

393. Patric, James H.
1976. Effects of wood products harvest on forest soil and water resources with emphasis on clear-cutting in moist climates. In The Scientific base for silviculture and management decisions in the National Forest System. U.S. Dep. Agric. For. Serv., Washington, D.C., p. 39-51.

The watershed management literature was reviewed to summarize effects of wood products harvest on forest soil and water resources. Effects on soil are minimal in eastern United States, largely a benefit of vigorous revegetation in humid climates. Slower and

lesser revegetation can accelerate erosion in arid western climates. Harvest always augments streamflow, with largest increases in most humid climates. The major effect on water quality is increased sediment loading accompanying accelerated soil erosion. Intelligently applied logging practices are the key to minimizing damage to soil and water.

394. Patric, James H.
1977. Soil erosion and its control in eastern woodlands. North. Logger 25(11): 4, 5, 22, 23, 31, 51, illus.

This paper, presented at a meeting of SCS woodland conservationists, reviews the evolution of concepts of soil erosion in eastern woodland over the past 40 years. Soil-water relations in the uncut and cut woodland are contrasted, with logging roads pinpointed as the most common cause of accelerated soil erosion. It is concluded that timber can be harvested professionally with little more than double the rates of soil erosion and stream sedimentation characteristic of the uncut forest, rates likely to persist no longer than a year or two after logging.

395. Patric, James H.
1978. Hydrology. In Yearbook of science and technology. McGraw-Hill Book Co., New York. p. 230-232.

396. Patric, J. H.
1978. Harvesting effects on soil and water in the eastern hardwood forest. South. J. Appl. For. 2: 66-73, illus.

Research on forest soil and water was summarized for eastern United States. Soil erosion remains close to geologic rates during responsibly conducted harvest of wood products but carelessly built logging roads can erode rapidly. Harvest increases water yields but has little influence on stormflow. Evidence to date suggests that harvest of stemwood seems unlikely to cause nutrient problems in soil or water.

397. Patric, J. H., and G. M. Aubertin.
1977. Long-term effects of repeated logging on an Appalachian stream. J. For. 75: 492-494, illus.

Watershed 2 on the Fernow Experimental Forest has been logged four times since the turn of the century. While little is known of how streams were affected by logging after 1901 or during World War II, the effects of diameter-limit cutting in 1958 and 1972 are well documented. Both cuts caused small increases in streamflow but had little effect on water quality by any criterion except turbidity, which was increased by poorly located and ill-managed logging roads. The evidence suggests that if responsible road practices are followed, continued diameter-limit cutting will not harm forest streams.

398. Patric, J. H., and L. K. Brink.
1977. Soil erosion and its control in the eastern forest. In Soil erosion: Prediction and control: Proc. Purdue Univ. Natl. Conf. on Soil Erosion. Special Publ. 21, Soil Conserv. Soc. Am. Ankeny, Iowa. p. 362-368.

This paper describes soil erosion in the undisturbed forest and how it is slightly accelerated by carefully regulated cutting. Logging roads are shown as the usual and major cause of severely accelerated erosion in the eastern forest. The Universal Soil Loss Equation is applicable for estimating erosion from logging roads in well-managed forest and from poorly managed woodland where the organic cover characteristic of forest soil has been destroyed.

399. Patric. J. H., and J. L. Gorman.
1978. Soil disturbance caused by skyline cable logging on steep slopes in West Virginia. J. Soil and Water Conserv. 33(1): 32-35, illus.

A URUS mobile skyline system removed an average of 32.6 $m^3$ (4,500 fbm) per hectare of hardwood logs from 16 ha (40 acres) of steep forest land in West Virginia. Six months after logging, we evaluated the area's

hydrologic performance. There was no evidence of reduced infiltration, increased bulk density, overland flow, or accelerated erosion, except on heavily used skid trails. The soil was severely disturbed (B horizon exposed) on less than 3 percent of the logged land; more than 90 percent was undisturbed.

400. Patric, James H., and Ernest M. Gould.
1976. Shifting land use and the effects on river flow in Massachusetts. J. Am. Water Works Assoc. 68(1): 41-45, illus.

A century ago, land formerly cleared for agriculture in Massachusetts began reverting to forest. It was thought that decreasing streamflow contributed to the decline of water power as the prime energy source in Massachusetts. Some further speculation concerns hydrologic effects of urbanization and of the 1938 hurricane on flow in these streams.

401. Patric, J. H., and J. H. Smith.
1978. Can cable logging better protect southern forests? Timber Harvesting 26(4): 32-33, illus.

This paper deals briefly with skyline cable logging as one means to lessen some effects of timber harvest on the forest soil, water, and recreation resources. Operating principles of the URUS, a small European skyline system, are outlined. Use of cable systems in West Virginia adequately protects most environmental values.

402. Patric, J. H., and G. R. Trimble, Jr.
1978. A broader view. (Letter to Editor.) Am. For. 84(3): 2-4.

403. Parker, B. L., R. S. Walters, H. B. Teillon, and C. M. Boulanger.
1977. Carbaryl residues in sugar maple sap. J. Econ. Entomol. 70(6): 785-788.

404. Parker, Johnson.
1977. Phenolics in black oak bark and leaves. J. Chem. Ecol. 3: 489-496.

Catechin, quercitrin, robinin, quercetin 3-methyl ether, scopoletin, cholorogenic acid, several leucoanthocyanins, and condensed and hydrolyzable tannins were identified in bark and leaves of Quercus velutina Lamarck. The concentrations of most phenolics in leaves increased as the growing season progressed, whereas those of most phenolics in bark remained essentially unchanged. Qualitative differences in bark and leaf phenolics among different trees were negligible.

405. Patric, J. H.
1976. Soil erosion in the eastern forest. J. For. 74: 671-677.

406. Paulick, R. K., and J. L. George.
1978. Determination of habitat components utilized by avian species in a planned suburban community. Research Briefs, Sch. For. Resour., Pa. State Univ. 11(1): 19-21.

407. Payne, Brian, and Richard DeGraaf.
1975. Economic values and recreational trends associated with human enjoyment of nongame birds. In Proc. Symp. Manage. For. Range Habitats Nongame Birds. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. WO-1. p. 6-10.

It is generally agreed that the enjoyment of nongame birds is an increasingly important recreational activity, perhaps rivaling hunting and fishing economically and in numbers of participants. But estimates of economic values and numbers of participants are scarce, and difficult to make. Land managers need better estimates of these values in deciding how much effort to devote to management of nongame birds.

408. Peters, John R., and Teresa M. Bowers.
1977. Forest statistics for Massachusetts. U.S. Dep. Agric. For. Serv. Resour. Bull. NE-48. 43 p.

A report on the second inventory of the forest resources of Massachusetts, including trends of change in commercial forest-land acreage, volume of growing stock, and sawtimber volume. The report contains 32 tables of statistical data on forest land, timber volume, annual growth, removals, and mortality, and output of timber products.

409. Peters, John R., and Teresa M. Bowers.
1977. Forest statistics for Rhode Island. U.S. Dep. Agric. For. Serv. Resour. Bull. NE-49. 38 p.

A report on the second inventory of the forest resources of Rhode Island, including trends of change in commercial forest-land acreage, volume of growing stock, and sawtimber volume. The report contains 32 tables of statistical data on forest land, timber volume, annual growth, removals, and mortality, and output of timber products.

410. Pham, C. H., H. G. Halverson, and G. M. Heisler.
1978. Precipitation and runoff water quality from an urban parking lot and implications for tree growth. U.S. Dep. Agric. For. Serv. Res. Note NE-253. 6 p.

The water quality of precipitation and runoff from a large parking lot in New Brunswick, New Jersey were studied during the early growing season, from March to June 1976. Precipitation and runoff from 10 storms were analyzed. The runoff was higher in all constituents considered except for P, Pb, and Cu. Compared with published values for natural waters, sewage effluent, and storm-water drainage from urban land, the parking lot runoff was not highly polluted during the study period, and it appears that such runoff is a satisfactory source of water for urban trees.

411. Pham, C. H., Howard G. Halverson, and Gordon M. Heisler.
1978. Red Maple (Acer rubrum L.) growth and foliar nutrient responses to soil fertility level and water regime. U.S. Dep. Agric. For. Serv. Res. Pap. NE-412. 7 p., illus.

In a greenhouse experiment, red maple (Acer rubrum L.) seedlings grew best when available soil N was 25 ppm, P was 25 to 75 ppm, and K was 75 to 100 ppm. Fertilization was effective only when soil moisture was not limiting.

412. Phillips, W., G. Simmons, and T. Corcoran.
1976. Spruce budworm and a computer-based mapping and information retrieval system. Maine For. Rev. 9: 13-15.

413. Pierce, Robert S.
1977. Forest soil. In W. E. Sopper, J. A. Lynch, and E. S. Corbett, eds. Water resources at the forest-urban interface. U.S. Dep. Agric. For. Serv. Pinchot Inst. Environ. For. Res. PA-2. p. 29-32.

This paper, part of a treatise on various aspects of water resources and urban forest relationships, deals with forest soil considerations. The prospect of using forests for human waste disposal is receiving increased attention. Research is urgently needed to determine the ability of forest soil to accept waste water for long periods without irreversible, deleterious effects, and with adequate natural uptake of nutrients to prevent stream and lake entrophication

414. Plass, William T.
1977. Seeding and planting to achieve land-management objectives. In Energy technology handbook. MrGraw-Hill Book Co., New York. p. 1-102 to 1-116.

Land disturbed by surface mining is generally an undeveloped resource. Evidence indicates this land is capable of producing tangible and intangible benefits to society. Land management options may be increased if consideration is given to potential spoil characteristics and landforms before mining. Once an appropriate land-management objective has been selected, planning proceeds to achieve it. When vegetation is required, planning includes soil preparation, selection of species, seeding and planting, and cultural treatments to maintain the vegetative cover and maximize yield.

Intensive development and management of land disturbed by surface mining can contribute to the nation's economy.

415. Plass, William T.
1977. Growth and survival of hardwoods and pine interplanted with European alder. U.S. Dep. Agric. For. Serv. Res. Pap. NE-376. 10 p., illus.

European black alder was planted as a nurse crop for five hardwood and five pine species. After 10 growing seasons, the alder had had little effect on the survival of the interplanted species, but their height and diameter were greater in association with alder. Foliar analysis showed that the interplanted species had used nitrogen fixed by the alder.

416. Plass, William T.
1978. Use of mulches and soil stabilizers for land reclamation in the eastern United States. In Reclamation of drastically disturbed lands. Am. Soc. Agron., Madison, Wis. p. 329-337.

The use of a mulch or soil stabilizer should be considered one of several treatment options in plans for reclaiming drastically disturbed areas. Such use should supplement, not substitute for, basic treatments required for stabilizing and revegetating soil. In the humid eastern United States, a mulch or soil stabilizer is often applied to help establish vegetation and control erosion by surface runoff. Treatments may include mulches or soil stabilizers alone or in combination. Selection of treatments should be based on requirements for erosion control, site and climatic variables that may affect the establishment of vegetation, and the cost of achieving the site-protection objectives.

417. Plass, William T.
1978. Reclamation of coal-mined land in Appalachia. J. Soil & Water Conserv. 33(2): 56-61.

Impressive improvements in reclamation technology in the Appalachian region have been made during the past decade through the efforts of concerned individuals from several states representing government, education, and industry. As an era for development of fundamental reclamation technology ends, this review summarizes current practices from mining through the successful establishment of vegetation. Recent accomplishments have encouraged optimism about revegetation. In the years ahead, research and experience will lead to practical land use options for land disturbed by mining.

418. Plumley, Harriet J.
1977. Design of outdoor urban spaces for thermal comfort. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 152-162.

Microclimates in outdoor urban spaces may be modified by controlling the wind and radiant environments in these spaces. Design guidelines were developed to specify how radiant environments may be selected or modified to provide conditions for thermal comfort. Fanger's human-thermal-comfort model was used to determine comfortable levels of radiant-heat exchange for various activities, clothing types, and climatic conditions. A comparison of these radiant quantities with measured and calculated quantities of radiant exchange expected for a person in urban spaces revealed several design guidelines.

419. Plumley, Harriet J., Harry T. Peet, and Raymond E. Leonard.
1978. Records of backcountry use can assist trail managers. U.S. Dep. Agric. For. Serv. Res. Pap. NE-414. 19 p., illus.

Backcountry visitor records of overnight site use can provide beneficial and practical information for making decisions on backcountry facilities. Data from the Long Trail in Vermont have been used to indicate the types of information that can be obtained from visitor use records.

420. Podgwaite, J. D., and R. B. Bruen.
1978. Procedures for the microbiological examination of production batch preparations of the nuclear polyhedrosis virus (Baculovirus) of the gypsy moth. For. Serv. Gen. Tech. Rep. NE-38. 8 p., illus.

Procedures for the microbiological examination of production batch preparations of the nuclear polyhedrosis virus of the gypsy moth are described. They include methods to count total bacteria and to detect fecal coliform and primary pathogenic bacteria in the preparations. These procedures are consistent with safety guidelines established by the U.S. Environmental Protection Agency (EPA) and they are adaptable for use in the examination of other insect virus preparations.

421. Podgwaite, J. D., and P. R. Galipeau.
1978. Effect of nucleopolyhedrosis virus on two avian predators of the gypsy moth. U.S. Dep. Agric. For. Serv. Res. Note NE-251. 2 p.

The nucleopolyhedrosis virus (NPV) of the gypsy moth was fed to black-capped chickadees and house sparrows in the form of NPV-infected gypsy moth larvae. Body weight and results of histological examination of organs of treated and control birds indicated that NPV had no apparent short term effect on these two important predators of the gypsy moth.

422. Pogge, Franz L.
1976. Book review: Shrubs and vines for northeastern wildlife. Castanea 41: 272-273.

423. Pottle, H. William, and Alex L. Shigo.
1974. Treatment of wounds on Acer rubrum with Trichoderma viride. Proc. Am. Phytopathol. Soc. 1: 142.

424. Pottle, H. W., A. L. Shigo, and R. O. Blanchard.
1977. Biological control of wound hymenomycetes by Trichoderma harzianum. Plant Dis. Rep. 8: 687-690.

425. Powell, Douglas S., and Teresa M. Bowers.
1978. A preview of Maryland's forest recource. U.S. Dep. Agric. For. Serv. Res. Note NE-252. 7 p., illus.

The 1976 forest survey of Maryland shows that the state has 2.5 million acres of commercial forest land, a decline of 13 percent since 1964. Ninety percent of it is in private ownership; 56 percent in sawtimber stands; 46 percent in the oak-hickory forest type. Timber volume has increased to 3.5 billion cubic feet of growing stock and 8.2 billion board feet of sawtimber. Seventy-three percent of the growing-stock volume is in sawtimber stands and 49 percent is in oak-hickory types. In a state that is dominated by hardwoods, loblolly pine is the single species with the most volume. Net growth exceeds removals for the state as a whole, but overcutting is occurring in certain units and in certain species.

426. Pritchard, W. Maurice, and Kuldip P. Chopra.
1977. Air pollution and urban climatology at Norfolk, Virginia. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 278-284.

The atmosphere at Norfolk is usually stable, with no strongly prevailing wind direction. Linear regression analyses of visibility data indicate a generally decreasing visibility trend between 1960 and 1972, with a possible trend reversal in later years. A 44 percent increase in the annual frequency of 0-4-mile visibility occurred in 1960-72. Similar analyses of precipitation data for 1960-74 show a slight increase in the annual number of days with precipitation exceeding 0.01 inch. The correlation coefficient between the annual frequencies of low (0-4-mile) visibility and days with precipitation greater than 0.01 inch was rather small and negative.

427. Pyszyński, W.
1977. Mechanism of formation of spiral grain in Aesculua stems: Dissymmetry of deformation of stems caused by cyclic torsion. Acta Soc. Bot. Pol. 46: 501-522.

Can asymmetrical recovery from wind twisting be blamed for spiral grain in trees? Pieces of Aesculus hippocastanum stems were twisted to the left and to the right in a laboratory device and then allowed to recover. Residual torsions to the right were always greater than those to the left. Also the fibrillar helix in the cell walls was always to the right. This asymmetry in mechanical properties of the stem may be responsible for the formation of right-oriented spiral grain in Aesculus subjected to natural wind action.

428. Pyszýnski, Wladyslaw.
1977. Complex wavy grain in the stem of Aesculus. Acta Soc. Pol. 46: 231-249.

Wavy grain, interlocked grain, and spiral grain are based on moving patterns of areas of cambium within which certain cellular events are oriented predominantly to the right or to the left, rather than randomly. Two types of wavy grain, long wave and short wave (about 80:1 in length) were found to be superposed onto the obvious spiral pattern. Both were explainable by cambial domain patterns, but the long-term spiral may have another basis in asymmetrical recovery of the wood from wind-induced torsion.

429. Rafaill, Barbara L., and Willis G. Vogel.
1978. A guide for vegetating surface-mined lands for wildlife in Eastern Kentucky and West Virginia. U.S. Dep. Inter. Fish and Wildl. Serv. FWS/OBS-78/84.

430. Reardon, Richard, William Metterhouse, and Robert Balaam.
1977. Traps for collecting adult parasites of the gypsy moth. J. Econ. Entomol. 70(2): 247-249.

Adult parasites of the gypsy moth, Lymantria dispar L., were collected in Malaise, McPhail, and sticky-tube traps located within three vertical strata: tree crown, bole, and ground. A total of 37,924 adults belonging to the families Braconidae, Chalcididae, Ichneumonidae, Sarcophagidae, and Tachinidae were collected. Malaise traps collected 99% of the Hymenoptera and 100% of the ichneumonid and braconid parasites of the gypsy moth.

Malaise and McPhail traps collected 71 and 27%, respectively of the tachinid parasites of the gypsy moth. The relative abundance of the captured tachinids Compsilura concinnata (Meigen), Blepharipa pratensis (Meigen), and Parasetigena silvestris (Robineau-Desvoidy) depended upon the type of trap.

431. Reethof, G., O. H. McDaniel, and G. M. Heisler.
1977. Sound absorption characteristics of tree bark and forest floor. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 206-217.

Results of basic research on absorption of sound by tree bark and forest floors are presented. Amount of sound absorption by tree bark was determined by laboratory experiments with bark samples in a standing-wave tube. A modified portable standing-wave tube was used to measure absorption of sound by forest floors with different moisture contents, with and without leaf litter, and with and without moss. The implications of the results are discussed in terms of the amount and mechanisms of sound absorption by entire forests.

432. Rexrode, Charles O.
1977. Cacodylic acid reduces the spread of oak wilt. Plant Dis. Rep. 61: 972-975.

Cacodylic acid was pressure-injected into the xylem of oak-wilt-infected trees to determine its effectiveness in preventing development of oak bark beetles and fungus mats and spread of the pathogen to healthy oaks. The treatment reduced by 75% the number of oak-wilt trees infested with oak bark beetles and by 61% the number producing the fungus mats. During the last two years of this 4-year study, the net reduction in number of diseased trees was 48% and the net reduction in number of active infection centers was 38%.

433. Rexrode, Charles O.
1978. Stem deformity in black cherry. U.S. Dep. Agric. For. Serv. Res. Pap. NE-411. 6 p., illus.

Insects, diseases, frost, and browsing by deer were the major sources of injury to terminal shoots of black cherry seedlings and saplings. Twenty-seven species of insects from 19 families and 5 orders were associated with young black cherry trees. Of these species, Archips spp., and Cecidomyia serotinae O.S., caused the most stem deformity in black cherry. Damage by these insects ranged from 0 to 43 percent per year on six study areas.

434. Rexrode, Charles O., and Robert E. Frame.
1977. Root graft incidence at oak wilt sites in West Virginia. Plant Dis. Rep. 61: 970-975.

In northeastern West Virginia, 29 oaks infected with oak wilt fungus were pressure injected with cacodylic acid. Chemical damage was found in 12 healty oaks that were adjacent to the injected trees. Thirty-one percent of the injected infected trees were connected by root grafts to the healthy trees; this study shows that root grafting between oaks in northeastern West Virginia is more prevalent and potentially more important in the incidence and spread of oak wilt fungus than was previously reported.

435. Reynolds, Hugh W.
1976. Furniture parts from pulpwood--a plant that did it. 4th Annu. Hardwood Symp. Hardwood Res. Counc., Cashiers, N.C. 4 p.

436. Reynolds, Hugh W.
1978. Yellow-poplar furniture: weatherwood finish. In Marketing and utilization of yellow-poplar: Symp. Proc. Knoxville, TN March 21-22, 1978. Inst. Agric. Univ. Tenn. p. 171-174

437. Reynolds, James W., [Hugh W.], and James Schroeder.
1977. System 6--a way to use small logs to make grade lumber for furniture cuttings. South. Lumberman 234 (2897): 9-10.

A new method for sawing small hardwood logs to grade lumber has been developed. The logs are bucked to

6-foot bolts, which are sawed to 1-inch boards in pallet-part sawmills. These boards are packaged for unit load handling into forced-air dryers and then into dry kilns. Hardwood lumber grade rules, modified for the 6-foot length, are used to establish board grades and lumber value. The kiln-dried boards are reduced to furniture cuttings in newly designed rough mills.

438. Reynolds, Hugh W., and James Schroeder.
1978. Furniture cuttings made from logging residue: the three-sided cant system. U.S. Dep. Agric. For. Serv. Res. Pap. NE-417. 4 p.

439. Rhodes, A. F., and E. Brennan.
1977. Vegetation and air quality. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 303-307.

Chemical monitoring is the classical way of defining air quality. However, the ability of plants to reflect changes in air quality must not be overlooked because certain species respond in definite ways to gaseous pollutants. In New Jersey, chemical-monitoring data supported plant-injury data for $SO_2$. While oxidant concentrations seemed to agree with plant data, recent changes in monitoring procedures have made the relationship unclear. Plant data have provided the only evidence for the presence of toxic amounts of fluoride in the air and have warned of the existence of as yet unidentified substances that impair air quality.

440. Roach, Benjamin A.
1977. A stocking guide for Allegheny hardwoods and its use in controlling intermediate cuttings. U.S. Dep. Agric. For. Serv. Res. Pap. NE-373. 30 p.

A stocking guide for stands of Allegheny hardwoods (sugar maple or sugar maple-beech with various admixtures of black cherry, red maple, white ash, sweet birch, and other species) on the Allegheny Plateau in

northwestern Pennsylvania. Included are procedures for evaluating stocking and stand conditions, thinning even-aged stands, determining minimum residual stocking, distributing the basal-area cut in a stand, and using the guide for selection cutting.

441. Robertson, Douglas L., and Rowan A. Rowntree.
1977. Behavorial significance of milieu: a consideration of two downtown settings. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 399-407.

Behavior patterns in parks and plazas in downtown Syracuse, New York, are discussed. After an introduction of the spaces and their principal users, fundamental concepts borrowed from ecological psychology are defined. Then using these concepts, the behavioral significance of the environment is illustrated in a comparison of two case studies. The concepts employed here are shown to allow a discussion of the important effect of environment on behavior without producing deterministic distortions.

442. Romberger, J. A.
1978. Meristems, growth, and development in woody plants: An analytical review of anatomical, physiological, and morphogenic aspects. Allanheld, Osmun & Co., and Universe Books, Montclair, N.J. 214 p.

A reprint with a new preface of Forest Service Technical Bulletin 1293, 1963.

443. Romberger, J. A. (General Ed.; R. H. Foote. L. Knutson, P. L. Lentz Assoc. Eds.)
1978. Beltsville symposia in agricultural research. 2. Biosystematics in agriculture. Allanheld, Osmun & Co., and John Wiley & Sons, Montclair, N.J., and New York. 340 p.

444. Romberger, J. A., and Robert A. Gregory.
1977. The shoot apical ontogeny of the Picea abies seedling. III. Some age-related aspects of morphogenesis. Am. J. Bot. 64: 622-630, illus.

Shoot apical meristems of young spruce seedlings are capable of rapid growth. Such meristems can produce new tissue to the extent of 20 to 35% of their own volume each day. Younger, smaller apices grow faster, but produce less because they are smaller. Most of the volume growth is invested in new stem internodes, but a variable fraction is retained by the meristem, increasing its "capital volume." This "investment ratio" is as high as 20% in meristems of 10-day-old seedlings, but declines to zero with age. Because the investment ratio determines apical meristem volume it has a large effect on shoot growth potential. We now need to know how it is controlled.

445. Rothwell, Frederick M., and Coleman Holt.
1978. Vesicular-arbuscular mycorrhizae established with Glomus fasciculatus spores isolated from the feces of cricetine mice. U.S. Dep. Agric. For. Serv. Res. Note NE-259. 4 p., illus.

Cricetine mice were trapped on two revegetated surface-mined areas--one with a freshly seeded grass-legume cover and one with an early successional grass-forb cover. Chlamydospores of Glomus fasciculatus isolated from the feces of these animals produced representative endomycorrhizae with corn under greenhouse conditions.

446. Rye, Arthur H., and Russell S. Walters.
1977. Maple spout modification shows no advantage. Natl. Maple Syrup Dig. 16(1): 17-19.

In an attempt to extract more sap from sugar maple tapholes, plastic spouts were modified by cutting a 1/2-inch long slot in the top and bottom of the part that is inserted in the taphole. A comparison of the modified spouts with unmodified spouts did not show a difference in either sugar content or volume of sap collected.

447. Safford, Lawrence O., and Miroslaw M. Czapowskyj.
1977. Effects of fertilization on the soil and foliar nutrient status and growth rate of a 15-year-old pioneer hardwood stand in eastern Maine. (Abstr.) Agron. Abstr. 1977: 183.

A previously thinned pioneer hardwood stand with a scattered spruce-fir understory was treated with lime, N, and P singly and in several combinations. Lime had little or no effect on nutrient content of foliage or growth response. Basal area growth of the aspen-birch stand responded primarily to N, increasing 66 percent in the first 2 years after treatment. NP combinations produced an even greater growth response.

448. Safford, L. O., H. E. Young, and T. W. Knight.
1977. Effect of soil and urea fertilization on foliar nutrients and basal area growth of red spruce. Univ. Maine Life Sci. Agric. Exp. Stn. Bull. 740. 27 p.

Individual mature red spruce trees growing on three soil series were fertilized with urea. Foliar nutrient levels and basal area growth were observed for 5 and 7 years, respectively. The nutrient content of red spruce needles varied greatly from year to year even though samples were collected during the dormant season. Soil series influenced foliage nutrient content of control trees as well as effect of N fertilizer on foliage nutrient level and basal area growth. The effects of urea on foliage nutrient level, needle weight, and basal area growth were neither great nor long lived.

449. Sarles, Raymond L., and David M. Emanuel.
1977. The mobile bark blower: an evaluation of performance and costs. U.S. Dep. Agric. For. Serv. Res. Pap. NE-368. 9 p., illus.

A custom-built bark blower truck (MOBLOW) developed in Oregon was tested for its effectiveness in applying bark mulches, sawdust, and shavings in the eastern United States. Tests determined the bark blower's performance and cost in mulching grass-legume seedings and shrub beds with 10 bark products or wood residues. Bark blower trucks built to MOBLOW specifications can effectively apply pine and hardwood bark products, sawdust, and wood shavings, but cannot handle unprocessed bark residues. Blower trucks can be used to blow shredded bark, sawdust, and shavings into barns, cattle sheds, poultry houses, show rings, and corrals, and to deliver hogged fuel.

450. Sarles, Raymond L., and David M. Emanuel.
1977. Hardwood bark mulch for revegetation and erosion control on drastically disturbed sites. J. Soil & Water Conserv. 32: 209-214, illus.

Use of bark as a mulch on seeded areas offers an outlet for large amounts of this timber mill residue. Experiments at five locations in southern West Virginia showed that bark compares favorably with straw and wood-fiber mulches for stabilizing soils on disturbed sites. Based on findings from the five experiments, bark applications of 30 and 50 cubic yards per acre are recommended. Slopes steeper than 2:1 and those facing south and west need the heavier application, as do sites exposed over winter. The experiments also demonstrated that improved equipment is needed to apply mulch efficiently.

451. Schmitt, D. M.
1977. The role of tree improvement in the Northeast: a geneticist's point of view. Northeast. For. Tree Improv. Conf. Proc. 25: 65-75.

The author estimates the amount of plantable forest land in the Northeast and concludes that there is enough (approximately 40.5 million acres) to support tree improvement programs. The balance of the paper describes biological factors that influence tree improvement investment decisions and how a forest geneticist's special knowledge can contribute to tree improvement opportunity analyses.

452. Schreiber, L. R., T. W. Jones, G. F. Gregory.
1978. Control of Dutch elm disease: comparison of benomyl and methyl 2-benzimidazolecarbamate hydrochloride, and two injection techniques. Plant Dis. Rep. 62: 761-765, illus.

Benomyl fungicide (methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate) as the 50% insoluble wettable powder formulation or as water-soluble methyl 2-benzimidazolecarbamate hydrochloride (MBC-HCl), was injected into American elm trees to control Dutch elm disease. The MBC-HCl solutions contained MBC at concentrations either approximately equal to or five to

six times that contained in the benomyl 50 WP. Chemicals were injected into the trunk 1 m above the soil line and 2.5 to 3.5 cm into the xylem or at the soil line in the outer two or three annual rings. Dutch elm disease was controlled by prophylactic treatments with MBC-HCl at the higher rate using both injection systems, and by the therapeutic treatment at the same rate with the second system. Residual fungitoxicants were found in trunk and twig samples in trees of all treatments but in a higher percentage of trees treated prophylactically with the higher rate of MBC-HCl.

453. Schuler, Albert T.
1978. The insulation board industry -- an econometric analysis. U.S. Dep. Agric. For. Serv. Res. Pap. NE-407. 8 p., illus.

An econometric model of the domestic insulation board industry was developed to identify and quantify the major factors affecting quantity consumed and price. The factors identified were housing starts, residential improvement activity, disposable personal income, productivity, pulpwood and residue prices, and power costs. Disposable personal income was the most important of these factors, affecting both quantity and price. Annual projections of quantity and price show quantity increasing by 30 percent and price by 106 percent by the year 1990.

454. Schuler, Albert T., H. H. Webster, and J. C. Meadows.
1977. Goal programing in forest management. J. For. 75: 320-324.

Managing resources for multiple use requires complex decisions that involve many diverse goals. Goal programing provides a way of analyzing such decisions and evaluating tradeoffs. The method was used in a pilot study to prepare a management plan for a 10,000-acre area on a national forest. It proved valuable both in maximizing the attainment of diverse goals and in showing that one goal was unrealistic.

455. Seegrist, Donald W.
1977. Two-way interaction when there is a linear relationship among the pairs of means in a factorial experiment. Northeast. For. Tree Improv. Conf. Proc. 25: 143-153.

This paper discusses the statistical analysis of genetic experiments when there is a linear relationship among the response of families planted at different locations. The hypothesis of no family x location interaction is equivalent to the hypothesis that there is a linear relationship among the family means and the slope of line among the means is unity (1.0). If the hypothesis of "no two-way interaction" is rejected, one should estimate the slope coefficient from the variance and covariance components of variance. A method of testing the hypothesis that the slope is zero is suggested. The test is based on ANOVA procedures.

456. Seegrist, Donald W., and Stanford L. Arner.
1978. Statistical analysis of linear growth and yield models with correlated observations from permanent plots remeasured at fixed intervals. In Growth models for long term forecasting of timber yields. Publ. FWS-1-78, School For. Wildl. Resour. Va. Polytech. Inst. and State Univ. p. 209-223.

457. Seliga, Thomas A.
1978. Summary of the first international symposium and workshop on acid precipitation and the forest ecosystem. Ohio State Univ. Rep. AS-S-101: 39 p.

458. Seliga, Thomas A., and L. S. Dochinger.
1976. First International Symposium on Acid Precipitation and the Forest Ecosystem. Water, Air, & Soil Pollut. 6: 135.

A brief report of the Symposium.

459. Semonin, Richard G.
1977. Temporal and spatial variability of rainfall pH. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 53-61.

The distribution of average rainwater pH over an area of 1,800 $km^2$ containing 81 collectors was determined from 25 storm events. The areal average of the data was pH 4.9, with a range of values from 4.3 to 6.8. A single storm event was studied to determine the change of pH as a function of time. The initial rain was pH 7.1, decreasing to 4.1. An excellent agreement was observed between the H+ deposition rate and the rainfall rate.

460. Sendak, Paul E.
1978. Birch sap utilization in the Ukraine. J. For. 76: 120-121, illus.

Birch sap is used to make beverages in the Ukraine. Unlike the maple sap used in North America for syrup and sugar, that from birch (Betula verrucosa Ehrh., B pubescens Ehrh.) is not boiled down; it is mixed with sugar and citric acid. Similarities between the birch and maple enterprises suggest that innovations in one might be adopted by the other.

461. Sendak, Paul E.
1978. Consumer preference for graded maple syrup. U.S. Dep. Agric. For. Serv. Res. Pap. NE-402. 11 p., illus.

The three grades of maple syrup and a commercial table syrup containing artificial flavor and 3 percent pure maple syrup were evaluated by 1,018 women in four cities. The results indicate that differences in preference for flavor are related to how close the respondents are to a maple syrup production region. Differences in preference among grades of pure maple syrup were slight and in reverse order of the quality implied by the Federal grading standard. Outside of the region of maple syrup production, differences in preference between pure maple syrup and the commercial table syrup were marked, and favored the commercial syrup.

462. Sendak, Paul E., and Lawrence D. Garrett.
1976. A different view of price trends--A letter to the editor. Natl. Maple Syrup Dig. 15(3): 14-15.

463. Sendak, Paul E., Mariafranca Morselli, and David E. Bee.
1978. Storage of U.S. Grade AA maple syrup in the retail package. J. Food Sci. 43(1978): 1002-1005, illus.

Six types of containers for maple syrup were evaluated under three controlled temperatures at four storage intervals. The contents of each container were analyzed for optical density (color), density pH, and flavor. If a good quality U.S. Grand AA maple syrup, properly hot-packed, is stored no longer than 6 months in the retail container at a temperature of 24°C, quality, as measured by color, density, pH, and flavor, will be maintained in the containers we evaluated. However, in some plastic containers, syrup stored for 9 and 12 months at 24° and 30°C, darkened enough to drop one grade level with a significant deterioration of flavor in one of the containers.

464. Shafer, Elwood L.
1977. Research needs for programs that provide natural environments for children. In: Children, Nature, and the Urban Environment. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-30, p. 215-217.

465. Shafer, E. L., Jr., and R. O. Brush.
1977. How to measure preferences for photographs of natural landscapes. Landscape Plann. 4: 237-256.

466. Shigo, A. L.
1976. Decay: A problem in both young and old trees. Am. Nurseryman 1: 24-27.

Decay is thought to be a problem only in old trees, but it is not. Wounds on small trees can also start the processes that could lead to decay. Too often it

is the accumulation of many small columns of decay early in the life of the tree that results in serious problems later in the life of the tree. A general review of compartmentalization and successions is given.

467. Shigo, Alex L.
1976. Decay in trees. N.H. For. Notes 127: 42-44, illus.

A general review of the decay process in living trees. Compartmentalization and successions are described. A decay model is given. Some key points to help the forester understand decay are given.

468. Shigo, A. L.
1977. When to call the tree doctor. McCall's (April): 55.

469. Shigo, A. L.
1977. Protecting your beautiful trees. Woman's Day (Nov.).

470. Shigo, A. L.
1977. Injection wounds in elm. In The current state of the art of Dutch elm disease control: Proc. Symp. No. 1, Natl. Arborist Assoc. p. 54-56.

471. Shigo, A. L.
1977. Quotables by Tom Stevenson. Am. Hortic. (April): 57.

472. Shigo, Alex L.
1977. Superior tree production fights tree wound fatalities. Am. Nurseryman 146(12): 10-11, illus.

We know now that some trees of the same species can respond more effectively to wounds than others. We must start programs to develop such trees, especially for our cities where wounding is a major problem.

473. Shigo, A. L.
1978. Tree decay: time to expand the concept. IUFRO Proc. Kassel, Germany. p. 298-305.

474. Shigo, Alex L.
1977. CODIT and the Shigometer work in the South. South. Lumberman 234(2): 10-11, illus.

CODIT is a model that explains in simple terms how decay develops in living trees. The Shigometer is an electrical device that detects decay in living trees. The CODIT system and the Shigometer work on trees in the South.

475. Shigo, Alex L.
1977. Communication of knowledge and needs between forest researchers and practicing foresters. North. Logger 25(12): 7, 38.

Forest researchers have produced a wealth of knowledge about trees, but not enough of it reaches the practicing foresters who need it and can use it. Some possible reasons for this are discussed, and the need for improving two-way communication between forest researchers and practicing foresters is emphasized.

476. Shigo, Alex L.
1977. A new look at tree care. Arboric. J. 3(3): 157-164, illus.

Decay is a major cause of damage to trees throughout the world. Most tree owners learn about decay after it is too late--when a tree falls on a car, a power line, or worse yet, a person. Much can be done to prevent decay and to minimize its impact on trees. The best way to help the tree is to understand the problem. What is decay? How does it start? What can be done about it? This paper gives some answers that have come from 17 years of research on decay, during which more than 5,000 trees--conifers, hardwoods, and tropical trees--were dissected and studied carefully.

477. Shigo, Alex L.
1977. Phialophora melinii: inoculations in wounded red maple. Phytopathology 67: 1333-1337, illus.

Isolations from discolored wood associated with wounds previously inoculated with Phialophora melinii in Acer rubrum showed that the fungus was present in all 1.5- to 26-month-old wounds. Hymenomycetes from natural sources were not isolated from wounds less than 4 months old. Wounds on trees inoculated with P. melinii yielded fewer Hymenomycetes than did non-inoculated wounds. The fungus thus acted as an aggressive invader and a long-term inhabitant of discolored wood.

478. Shigo, Alex L.
1978. Dealing with decay factors in our urban forests. Weeds, Trees and Turf 17(11): 14-18, illus.

We have tamed our urban trees. We are responsible for their care. A quick look at the condition of some of our urban trees will show that we have not met our responsibility. We seem to see more and more urban trees in trouble. Is it because we are becoming more aware of our trees? Or is it because the condition of our trees is declining? Probably both.

479. Shigo, Alex L., and Richard Campana.
1977. Discolored and decayed wood associated with injection wounds in American elm. J. Arboric. 3(12): 230-235.

Dissection of 80 large American elm trees with a chainsaw revealed discolored and decayed wood associated with holes drilled for injections to control Dutch elm disease. Discolored wood was associated with every injection wound; injection wounds made in several successive years caused severe internal injuries. Until less injurious injection methods are developed, we suggest that injection holes be as small, shallow, clean-edged, and few as possible. Later injection

sites should be at least 46 cm (18 in) above and not directly over older ones. If possible, drilling should be avoided at budbreak and in the valleys of fluted roots.

480. Shigo, A. L., and H. G. Marx.
1977. Compartmentalization of decay in trees. U.S. Dep. Agric. For. Serv. Agric. Bull. 405. 73 p.

A model system is given that describes how decay develops in living trees. The system is called CODIT, an acronym for Compartmentalization Of Decay In Trees. An understanding of CODIT will help to clarify many misconceptions about decay in living trees.

481. Shigo, Alex L., and Walter E. Money, and Dale I. Dodds.
1977. Some internal effects of Mauget tree injections. J. Arboric. 3(11): 213-220, illus.

Negligible amounts of discolored wood and cambial dieback were associated with control Mauget injection wounds (no chemicals added) made 1 year earlier on red maple, white oak, and shagbark hickory. Columns of discolored wood and some cambial dieback were associated with wounds that had been injected with Bidrin or Meta-Systox-R. Columns of discolored wood and very little cambial dieback were associated with wounds that had been injected with Fungisol or Stemix. Injured tissues associated with all wounds were compartmentalized in the wood present at the time of injection; wood that formed subsequently was not infected.

482. Shigo, Alex L., and Walter C. Shortle.
1977. "New" ideas in tree care. J. Arboric. 3(1): 1-6.

Some controversy has arisen over statements made recently in this journal about wound dressings, cavity fillings, and boring holes in trees. Some quotations from other researchers are given here as support for the statements. Often what is considered new is really a restatement of older information, or sound older

information may be combined with information from recent studies to form conclusions that can be considered new.

483. Shigo, Alex L., Walter Shortle, and Peter Garrett. 1977. Compartmentalization of discolored and decayed wood associated with injection-type wounds in hybrid poplar. J. Arboric. 3(6): 114-118, illus.

Sixty trees representing nine different clones of Populus deltoides X P. trichocarpa hybrids were wounded in 1975, each tree receiving 14 drill wounds. Dissections of these trees after 6 months revealed several patterns of healing, ranging from poor closure and compartmentalization to excellent closure and compartmentalization. The results show that it is difficult to generalize on the healing patterns of injection-type wounds. One tree may have a strong healing response and another tree of the same species may have a weak response. The wound response seems to be under genetic control.

484. Shigo, Alex L., Walter C. Shortle, and Peter W. Garrett. 1977. Genetic control suggested in compartmentalization of discolored wood associated with tree wounds. For. Sci. 23: 179-182, illus.

Nine trees in three clones of Populus deltoides X P. trichocarpa compartmentalized effectively the discolored wood associated with wounds: after 6 months only small columns of discolored wood were associated with the 14 experimentally inflicted wounds per tree. Eighteen trees in six other clones compartmentalized poorly the discolored wood associated with wounds: after 6 months large columns of discolored wood were associated with the wounds. Wound closure and tree diameter were not related to percentage of stem that was discolored. The results suggest that compartmentalization of discolored wood associated with wounds may be under genetic control.

485. Shigo, Alex L., Walter C. Shortle, and Julian Ochrymowych.
1977. Detection of active decay at groundline in utility poles. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-35. 26 p., illus.

Active wood decay at groundline in in-service utility poles can be detected by a skilled inspector using:
1. A knowledge of basic patterns of decay.
2. Recognition of obvious signs of decay.
3. Proper interpretation of information obtained from a pulsed-current meter--Shigometer®--used with various probes and probing techniques.

486. Shigo, A. L., and C. L. Wilson.
1977. Wound dressings on red maple and American elm: effectiveness after 5 years. J. Arboric. 3: 81-87.

Closure and internal compartmentalization of wounds on red maple and American elm were not stimulated by dressings of an asphalt-based material, orange shellac, or polyurethane varnish. After 5 years, decay fungi had infected many treated and control wounds. Some trees closed wounds rapidly; others closed wounds slowly regardless of the treatments.

487. Shigo, A. L.
1978. Wounded trees. Changing Times 32 (June): 37.

488. Shigo, A. L., and R. Campana.
1977. Discoloration and decay associated with treatment wounds from chemical injection of elms to control Dutch elm disease. Proc. Am. Phytopathol. Soc. 4: 218-219.

489. Shigo, Alex L., Nelson F. Rogers, E. Allen McGinnes,Jr., David T. Funk.
1978. Black walnut on Kansas strip mine spoils: some observations 25 years after pruning. U.S. Dep. Agric. For. Serv. Res. Pap. NE-393. 14 p., illus.

Dissections of 14 slow-growing black walnut trees on a strip-mine site revealed that bands of discolored heartwood were associated with pruned and nonpruned branch stubs. Ring shakes were associated with a few pruned and nonpruned stubs, especially with groups of stubs at the same position on the stem. The advantage of early pruning was that even the defects that developed were compartmentalized within the small nonmerchantable central core that was the diameter of the tree at the time of pruning.

490. Shortle, W. C.
1976. Tree care: A new look. Proc. Midwest. Chapter Int. Shade Tree Conf. p. 33-35.

491. Shortle, Walter C.
1977. Decay in trees: evaluating the hazard tree. Park Maintenance 30(5): 17-18.

Decay in trees can create a hazard to people and property. One of the ways to tell the hazard potential of a tree is to look for obvious indicators of decay - wounds that begin to decay and fruit bodies of decay fungi. Sometimes there are no obvious indicators. A new electronic device, the Shigometer, can help determine the internal condition of trees. To prevent decay problems, begin a program to keep trees healthy, and be aware of new information on decay and tree care.

492. Shortle, W. C.
1977. Compartmentalization of decay in red maple and hybrid poplar trees. Proc. Am. Phytopathol. Soc. 4: 86.

493. Shortle, W. C., and E. B. Cowling.
1978. Development of discoloration, decay, and microorganisms following wounding of sweetgum and yellow-poplar trees. Phytopathology 68: 609-616.

494. Shortle, W. C., and E. B. Cowling.
1978. Interaction of live sapwood and fungi commonly found in discolored and decayed wood. Phytopathology 68: 617-623.

495. Shortle, W. S., A. L. Shigo, P. Berry, and J. Abusamra.
1977. Electrical resistance in tree cambium zone: relationship to rates of growth and wound closure. For. Sci. 23: 326-329.

Resistance to a pulsed electric current in the cambial zone of sprout red maple and hybrid poplar was inversely proportional to rate of growth. In hybrid poplars, resistance was also inversely proportional to rate of wound closure, but not to amount of wood discoloration.

496. Shortle, W. C., A. L. Shigo, J. Ochrymowych.
1978. Patterns of resistance to a pulsed electric current in sound and decayed utility poles. For. Prod. J. 28(1): 48-51, illus.

Patterns of electrical resistance measured at groundlines were determined for 174 utility poles representing combinations of 7 species and 5 preservative treatments. Criteria developed from these patterns correctly indicated the internal condition of wood in 161 (93%) of 174 poles. Internal voids were detected during drilling prior to taking electrical measurements in seven poles. A decrease of one or more readings to 75 percent of the highest reading generally indicated decayed wood. Sometimes no decayed wood was found when this criterion was applied, but no decayed wood escaped detection within the limits of our ability to see symptoms of decay. A problem in distinguishing between sound and decayed wood in some poles was caused by off-scale readings.

497. Sisterson, Douglas L., and Richard A. Dirks.
1977. The urban moisture climate. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 26-35.

Data collected on 26 July 1974 as a part of project METROMEX in St. Louis show the three-dimensional structure of the urban moisture field. Mesoscale dry regions at the urban surface, corresponding to large residential and light industrial land use, were responsible for a reduction in specific humidity in the urban mixing layer. Anthropogenic sources and sinks of water vapor were estimated and found to be insignificant as summer daytime mesoscale influences on the atmospheric water balance of the urban area. The effects of reduced moisture in the urban area are directly related to the urban heat island, visibility, fog, precipitation, and human comfort in our cities.

498. Skipka, K. J., and D. B. Smith.
1977. Development of alternative sulfur dioxide control strategies for a metropolitan area and its environs, utilizing a modified climatological dispersion model. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 285-294.

Alternative control strategies were developed for achieving compliance with ambiant air quality standards in Portland, Maine, and its environs, using a modified climatological dispersion model (CDM) and manipulating the sulfur content of the fuel oil consumed in four concentric zones. Strategies were evaluated for their impact on ambient air quality, economics, and fuel oil resources. Based on these evaluations, a control strategy best suited for meeting the needs of the Portland area could be recommended.

499. Smith, H. Clay.
1977. Height of tallest saplings in 10-year-old Appalachian hardwood clearcuts. U.S. Dep. Agric. For. Serv. Res. Pap. NE-381. 6 p., illus.

Stem characteristics, mainly height, of the tallest hardwood saplings in 10-year-old circular clearcut openings were evaluated for several Appalachian hardwoods in West Virginia. Heights of the tallest saplings were not influenced by cardinal directions on two oak sites. Saplings were taller near the center of 150-, 200-, and 250-foot openings than saplings in

the center of the 50- and 100-foot openings. Saplings in the larger openings (150- to 250-foot) were significantly taller near the opening center than the tallest saplings along the borders of the same size openings. For small openings (100-foot or less), the border effect was present throughout the openings.

500. Smith, H. Clay.
1977. Changes in tree density do not influence epicormic branching of yellow-poplar. U.S. Dep. Agric. For. Serv. Res. Note NE-239. 3 p.

Epicormic branching was studied in a West Virginia yellow-poplar stand thinned to various tree density levels. Study trees in the 55- to 60-year-old second-growth stand were primarily codominant in crown class with 32 to 48 feet of log height. Eight-year study results indicated that yellow-poplar trees in this age class and locale could be thinned without serious loss of log quality from epicormic branching.

501. Smith, H. Clay.
1977. Killing grapevines with herbicides. North. Logger 25(7): 9, 33.

Grapevines, along with snow or ice, can seriously damage hardwood trees, especially those in even-aged stands on good oak sites. Four mistblowing treatments and one pellet treatment was used to kill grapevines in West Virginia. Study results indicated that all herbicides killed grapevines, but the most effective treatment was was with Tordon 10K pellets.

502. Smith, H. Clay.
1977. Results of precommercial thinning in very young Appalachian hardwood stands. North. Logger 26(6): 24-25.

Studies of early crop-tree release at three sites on the Fernow Experimental Forest indicated that yellow-poplar, black cherry, northern red oak, or sugar maple crop trees of seedling origin should not be released 7 to 9 years after clearcutting. Release usually did not

stimulate height growth, and it had little effect on diameter growth. Exceptions were dominant and codominant red maple sprouts on a fair-quality site (site index 60 for northern red oak).

503. Smith, Clay.
1978. Skyline cable logging on the Fernow Experimental Forest. North. Logger 27(5): 20-32, illus.

The URUS skyline cable logging system was tested in West Virginia for about 2 years by the U.S. Forest Service. Results of these tests are summarized in this article.

504. Smith, H. Clay, and N. I. Lamson.
1977. Stand development 25 years after a 9.0-inch diameter-limit first cutting in Appalachian hardwoods. U.S. Dep. Agric. For. Serv. Res. Pap. NE-379. 4 p., illus.

This report is a case history of stand development 25 years after a 9.0-inch diameter-limit cutting in a primarily second growth 40- to 45-year-old Appalachian hardwood stand. Some old residual trees from the early 1900 logging era were scattered throughout the stand. In 1950, a 9.0-inch diameter-limit cutting removed 8,650 board feet per acre and reduced the basal area from 97 to 24 square feet per acre. Twenty-five years after this 1950 cutting, the total sawlog volume was 7,425 board feet per acre with a basal area of 98 square feet per acre. Oaks accounted for 42 percent of the sawlog-size trees and 45 percent of the sawlog stand volume.

505. Smith, H. Clay, and G. W. Wendel.
1976. Potential for strip-clearcutting in Appalachian hardwoods. W. Va. For. Notes 56: 16-19, illus.

Strip-clearcutting is a systematic method of clearcutting a forest. It is being evaluated on the Fernow Experimental Forest in West Virginia as an alternative to patch clearcutting. The strip-clearcutting method is potentially acceptable on aesthetic,

silvicultural, and stand-regulation grounds, and could be used for forest management in Appalachian hardwoods.

506. Smith, Christopher J.
1977. Visual and functional components of the built environment: A case study of urban residential neighborhoods. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 368-376.

The hypothesis that visual and functional characteristics of neighborhoods influence the psychological well-being of residents was tested. An informal test by a survey of advertising strategies for selling real estate was first used. Second, data from a variety of published sources were used to identify some of the underlying dimensions of residential neighborhoods. The dimensions were used as independent variables to predict three different measures of psychological well-being in former mental patients. The results partially supported the assumed relationship by demonstrating that neighborhood type appeared to influence the patients' recuperation.

507. Smith, D. E., A. L. Shigo, L. O. Safford, and R. Blanchard.
1976. Resistances to a pulsed electric current reveal differences between nonreleased, released, and released-fertilized paper birch trees. For. Sci. 22: 471-472.

A pulsed electric current was used to determine the resistance of cambial-zone tissues in pole-sized paper birch trees 3 years after thinning and fertilization treatments. Resistances in nonreleased (control) trees were significantly greater than those in released trees which had, in turn, resistances significantly greater than released fertilized trees.

508. Smith, Harvey R.
1977. Change in somatic growth rates of *Microtus pennsylvanicus* as a result of cross-fostering with *Peromyscus leucopus*. U.S. Dep. Agric. For. Serv. Res. Note NE-235. 4 p., illus.

A litter of five meadow voles (Microtus pennsylvanicus) was cross-fostered on a white-footed mouse (Peromyscus leucopus). All Microtus pups survived through weaning. Daily weight gain was 0.30 g before weaning and 0.96 g after weaning. When weaned, the Microtus pups were approximately 1/3 normal size for that stage of development. The timing of postnatal physiological events was not affected by cross-fostering.

509. Smith, Harvey R., and Robert W. Campbell.
1978. Woodland mammals and the gypsy moth. Am. For. 84(5): 22-24, 56, illus.

510. Smith, Harvey R., and George D. Whitney.
1977. Intraperitoneal transmitter implants--their biological feasibility for studying small mammals. In Proc. 1st Int. Conf. Wildl. Biotelemetry, Laramie, Wyoming, July 1977. p. 109-117.

The biological feasibility of intraperitoneal transmitter implants in small mammals was evaluated by studying survival of free-living Peromyscus leucopus from July 1975 to March 1976. Anticipated deleterious effects of peritoneal implantation did not occur. Overwintering survival was not reduced in transmitter-carrying animals. The advantages of intraperitoneal implants over subcutaneous implants or radio collars are discussed. The study concluded that peritoneal implants are not only feasible but biologically optimal.

511. Smith, James L., and Howard G. Halverson.
1976. Forest ecology. In McGraw-Hill yearbook of science and technology, 1976. McGraw-Hill Book Co. New York. p. 187-189.

Control of solar light and heat can help provide a proper growth environment for forests. Models were developed to predetermine the length and location of shadows at any time and for any location in the contiguous United States. Other model uses include a time sequence simulation of shadow presence at any point, given certain overstory conditions.

512. Smith, William H., and Leon S. Dochinger (eds.). 1976. Air pollution and metropolitan wood vegetation. U.S. Dep. Agric. For. Serv. Pinchot Inst. Environ. For. Stud. p. 1-74.

This report sets forth a program of research designed to achieve an acceptable level of understanding of the relationships between air contaminants and woody plants in the metropolitan northeast. Research needs are divided into categories of top and high priority for solving air pollution problems of forest and urban management in and around northeastern centers.

513. Snow, J. A., R. D. Schein, and W. J. Moroz. 1977. Characterization of biological particulate loads in metropolitan air. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 323-332.

The atmospheric particulate load includes a wide range of naturally occurring particles of biological origin that serve as a reservoir of allergenic agents in respiratory disease. Improved knowledge of potential aeroallergens is needed by medical clinicians. Aims are to better characterize air spora, qualitatively and quantitatively, and determine daily (by hour) periodicities of occurrence and prevalence of different kinds of spores, and seasonal variations. Main emphasis is on fungus spores about which least is known though they occur in considerable numbers. Efficient volumetric samplers provide time-related deposits of air spora at three sites in Pennsylvania.

514. Solomon, Dale S. 1977. Status of growth and yield information for northern forest types. In Proc. Symp. Intensive Culture of Northern Forest Types. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-29. p. 251-260.

Existing regional growth and yield information for most of the northern forest types is summarized by species. Present research is concentrated on growth-simulation models, constructed by either aggregating available

information or through individual tree growth studies. A uniformity of more refined measurements is needed so that future growth models can be tried for other species and forest types.

515. Solomon, Dale S.
1977. A growth model of natural and silviculturally treated stands of even-aged northern hardwoods. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-36. 30 p., illus.

A computer program simulates the development and treatment of even-aged northern hardwoods in New England. From the sapling stage, it projects stand growth to any rotation age or diameter, using available stocking guides, yield-table data, and gross growth estimates. Thinning and final harvest yields are presented by species and quality classes, and the effects of silvicultural treatments (or lack of treatments) on long-term stand response are incorporated.

516. Solomon, Dale S.
1977. The influence of stand density and structure on growth of northern hardwoods in New England. U.S. Dep. Agric. For. Serv. Res. Pap. NE-362. 13 p., illus.

Growth of northern hardwoods over a 10-year period was studied in plots that were treated to produce residual densities of 40, 60, 80, and 100 square feet of basal area per acre with stand structures of 30, 45, and 60 percent sawtimber. Both diameter and basal-area growth are tabulated by treatment and species.

517. Solomon, Dale S.
1977. Growth rates of northern hardwoods under uneven-age management. North.Logger 25(8): 18-38.

In a study of uneven-age management of northern hardwoods, components of average annual growth were calculated for residual stand densities of 40, 60, 80 and 100 square feet of basal area per acre, each having a range of stand structures of 30, 45, and 60 percent in

sawtimber-size trees. The treatment that maintained high-quality sawtimber production and acceptable sawtimber growth and balanced poletimber production was one that produced a residual stand of 80 square feet of basal area per acre, with 45 percent sawtimber-size trees.

518. Solomon, Dale S., and Barton M. Blum.
1977. Closure rates of yellow birch pruning wounds. Can. J. For. Res. 7: 120-124, illus.

In August 1963, 135 yellow birch trees (Betula alleghaniensis Britt.), averaging 5.08 cm in diameter at 1.37 m aboveground were pruned to two-thirds of their total height. Larger pruning wounds had a faster rate of closure but required more time to close than small wounds. The width and length of the pruning wound, as well as the diameter growth of the tree, were significantly related to closure rate. Although shade had no significant effect on closure rate, it reduced formation of epicormic branches.

519. Solomon, Dale S., and Barton M. Blum.
1977. Effects of pruning height on the diameter growth of yellow birch. U.S. Dep. Agric. For. Serv. Res. Note NE-233. 3 p., illus.

The diameter growth rate of pruned trees increased the second year after pruning, whereas the diameter growth of unpruned trees was not as fast during the second year. Diameter growth rate was positively correlated with the height to which all branches were pruned. After the pruning shock of the first year, trees pruned to 50 percent of their height showed the greatest cumulative growth in diameter.

520. Sopper, W. E., J. A. Lynch, and E. S. Corbett.
1976. Nature and magnitude of non-point source pollution from forests. In Proc. Workshop on Non-point Sources of Water Pollution: Problems, Policies, and Prospects. Purdue Water Resour. Center, Purdue Univ. p. 104-120.

Section 304 of the Federal Water Pollution Control Act (92-500) directs EPA to issue to the states guidelines for identifying and evaluating the nature and extent of non-point sources of pollution from "silvicultural activities". Information on the existing water quality of streamflow emerging from undisturbed forested areas and the natural variations that occur are presented. The relative impacts on water quality of various forest management practices conducted on experimental watersheds are given.

521. Sopper, W. E., J. A. Lynch, and E. S. Corbett (eds.). 1977. Water resources at the forest-urban interface. U.S. Dep. Agric. For. Serv. Pinchot Inst. Environ. For. Res. PA-2. 47 p.

A program of research designed to seek solutions for the more urgent problems related to urban water supply and wastewater disposal in the metropolitan Northeast is presented. Background information and research priorities are provided for 72 problem areas. The scope of the report ranges from the effects of timber harvesting, recreation, and land use changes on water quality to the effects of wastewater renovation by the forest ecosystem on public health, its socioeconomic aspects and public acceptance.

522. Spencer, E. L., S. H. Surgenor, and R. E. Leonard. 1976. Backcountry research. The Mahoosuc Laboratory. Appalachia 41(8): 101-109.

The Mahoosuc Range is a well-defined geographic area encompassing a variety of ecological communities which, until recently, received little recreational use. Conditions are ideal for the establishment of an outdoor laboratory to study the interactions between recreationists and the backcountry. Baseline data on vegetation communities and existing trails is gathered for future comparisons. Methods for acquiring valuable use figures are self-registration, electric counters, and caretaker interviews. Water quality sampling and lysimeter tests are additional studies designed to evaluate human impact. AMC cost statistics are discussed briefly. The results of this research can provide a basis for knowledgeable management decisions.

523. Stark, Thomas F., and David R. Miller.
1977. Effect of synthetic surfaces and vegetation in urban areas on human energy balance and comfort. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 139-151.

524. Stern, E. George.
1977. Performance of lumber pallets of conventional and improved designs. Va. Polytech. Inst. and State Univ., Wood Res. and Wood Constr. Lab. William H. Sardo, Jr. Pallet and Container Res. Lab. Bull. 154. 36 p., illus.

Twenty-four randomly selected 52- by 42-inch mixed-hardwood warehouse and exchange pallets of old and improved designs were tested. The pallets of improved design had up to 20 percent higher stiffness, 21 percent higher rigidity, 25 to 30 percent lower bending resistance of stringers, and at least 10 times the resistance to impact of lift-truck forks. Pallets of improved design should have 78 percent longer life and a 44 percent lower cost per use.

525. Stern, E. George.
1978. Performance of warehouse and exchange pallets made of six western woods. Va. Polytech. Inst. and State Univ., Wood Res. and Wood Constr. Lab. William H. Sardo, Jr., Pallet and Container Res. Lab. Bull 156. 48 p., illus.

Fifty-seven 48 by 40-inch warehouse and exchange pallets of green or partially seasoned western hardwoods (Fremont cottonwood, California white and black oak, Oregon white oak, or bigleaf maple deckboards on Oregon white oak stringers) or western softwood (coast type Douglas-fir) were tested for stiffness, rigidity, and load-carrying capacity. Deflections of pallet centers after applying a 1000-pound concentrated load were less than 1/2 inch for all pallets. Nailed pallets were more rigid than stapled hardwood pallets. The average load-carrying capacity was 3,090 pounds for the hardwood and 2,025 pounds for the softwood pallets.

526. Steuer, Ralph E., and Albert T. Schuler.
1977. An interactive multi-objective linear programing approach to a problem in forest management. Oper. Res. J. 26(2): 254-269.

The major obstacle in applying previously developed mathematical programing procedures to multiple-use forest management has been the difficulty in assessing the appropriate criterion weights. An interactive multiple-objective linear programing approach, not requiring criterion weights, uses a combination of linear programing and vector-maximum technologies. At each interaction, the cone generated by the gradients of the multiple objectives is contracted. On the last two iterations, the most acceptable efficient extreme point is ultimately identified with the aid of a filtering device.

527. Stevens, Robert E., J. Wayne Brewer, and Daniel T. Jennings.
1978. Life history and habits of Coleotechnites edulicola (Gelechiidae), a pinyon needle miner in the Southwest. J. Lepidopterists' Soc. 32: 123-129.

528. Stevens, Robert E., and Daniel T. Jennings.
1977. Western pine-shoot borer: a threat to intensive management of ponderosa pine in the Rocky Mountain area and Southwest. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. RM-45, 8 p.

529. Summers, Peter W.
1977. Application of the urban mixing-depth concept to air-pollution problems. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 273-277.

A simple urban mixing-depth model is used to develop an indicator of downtown pollution concentrations based on emission strength, rural temperature lapse rate, wind speed, city heat input, and city size. It is shown that the mean annual downtown suspended particulate levels in Canadian cities are proportional to the

fifth root of the population. The implications of this and other results of the model are discussed.

530. Superfesky, Michael J., and George P. Williams.
1978. Shear strength of surface-mine spoils measured by triaxial and direct shear methods. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-39. 15 p.

Results of measurements of seven surface-mine spoils by triaxial and direct shear methods indicated that the direct shear method may be used for evaluating the shear strength parameters of surface-mine spoils. The average angle of internal friction determined by shear testing was 38.6°; the average value for the triaxial method was 33.4°. The average value of cohesion determined by direct shear testing of dry materials was .077 bar; the average value of cohesion determined for the triaxial method was .100 bar. Soaking specimens immediately before direct shear testing reduced the average angle of internal friction by 8.2°; there was no significant change in cohesion.

531. Surgeoner, Gordon A., and William E. Wallner.
1978. Evidence of prolonged diapause in prepupae of the variable oak leaf caterpillar, Heterocampa manteo. Environ. Entomol. 7: 186-188.

532. Surgeoner, Gordon A., and William A. Wallner.
1978. Foliage consumption by the variable oak leaf caterpillar, Heterocampa manteo (Lepidoptera: Notodontidae), its use in defoliation predictions. Can. Entomol. 110: 241-244.

533. Talerico, Robert L., Carlton M. Newton, and Harry T. Valentine.
1978. Pest-control decisions by decision-tree analysis. J. For. 76: 16-19, illus.

Pest-control decisions are often made under conditions of uncertainty and without consideration of all the alternatives. A decision-tree approach makes it

possible to determine the best alternatives without resolving the uncertainty. The method can be used to decide which of various control alternatives has the lowest expected cost.

534. Talerico, Robert L., John E. Walker, and Thomas E. Skratt.
1977. Progress toward quantifying insect defoliation with advanced photometric methods. Proc. 6th Bienn. Workshop Aerial Color Photogr. in the Plant Sci. and Related Fields. Colo. State Univ., Fort Collins. p. 60-71.

During 1975 and 1976 aerial photographs and satellite imagery were investigated as more objective ways to detect and delineate gypsy moth defoliation in central Pennsylvania. A camera photometric calibration technique and a new information extraction method, photometric interpretation, were used to analyze color infrared aerial film. A mathematical relationship was derived that relates ground defoliation estimates to a reflectance defoliation index. Several methods of displaying defoliation intensity including data from Landsat digital tape records, are demonstrated.

535. Talerico, R. L., J. E. Walker, T. A. Skratt.
1978. Quantifying gypsy moth defoliation. Photogramm. Eng. and Remote Sensing 44: 1385-1392, illus.

Currently, estimates of gypsy moth (Lymantria dispar (L.)) defoliation are subjective judgments of the amount of foliage that has been removed from a tree or a forested area. These estimates can be made by observers on the ground or in aircraft, or from aerial photographs. A precise, objective method for measuring and mapping insect defoliation from aerial photos is the use of color-infrared film (at a scale of 1:31,640) with the Scene Color Standard (scs) analysis. This photo-derived defoliation measure includes terms for IRR reflectance, green reflectance at maturity, and average red, green, and infrared reflectance of the crown. The correlation of measurements by the scs analysis with ground observations of

defoliation was $R^2 = 0.78$. scs technology also can be used in monitoring spray programs for uniformity of application and effectiveness in protecting foliage.

536. Talerico, Robert L., Robert W. Wilson, Jr.
1978. A sampling device for counting insect egg clusters and measuring vertical distribution of vegetation. U.S. Dep. Agric. For. Serv. Res. Note NE-250. 4 p., illus.

The use of a vertical sampling pole that delineates known volumes and position is illustrated and demonstrated for counting egg clusters of N. sertifer. The pole can also be used to estimate vertical and horizontal coverage, distribution or damage of vegetation or foliage.

537. Thomas, Jack Ward, Richard M. DeGraaf, and Joseph C. Mawson.
1977. Determination of habitat requirements for birds in suburban areas. U.S. Dep. Agric. For. Serv. Res. Pap. NE-357. 15 p.

Songbird populations were related to habitat components by a method that allows the simultaneous determination of habitat requirements for a variety of species. Through correlation and multiple-regression analysis, 10 bird species were studied in a suburban habitat, which was stratified according to human density. Variables used to account for bird distribution included aspects of vegetation, human activity, and structures.

538. Tignor, G. H., H. M. Mazzone, and R. E. Shope.
1976. Serologic studies with the baculoviruses of P. dispar and N. sertifer. In Proc. 1st Int. Colloq. Invertebr. Pathol. and 9th Annu. Meet. Soc. Invertebr. Pathol. (Queen's Univ., Kingston, Ont. Canada, 1976). p. 13-14.

Adult mice depleted of antibody cells by Cytoxan or by thymectomy were exposed to polyhedra of the nucleopolyhedrosis virus of P. dispar and N. sertifer by the following routes: oral intubation, foot pad

inoculation, nasal instillation, eye irritation, and feeding. In addition, guinea pigs whose depressed cell-mediated immune function was affected by cortisone were exposed to polyhedra of these viruses through applications to shaved backs, areas of intact skin, and areas on a single ear. No deleterious effects were observed from virus exposure, indicating that immuno-suppressed animals would not be infected by the viruses tested. In addition, strains of the viruses from various parts of the world were found, by the technique of complement fixation, to be serologically identical.

539. Timson, Floyd G.
1978. Develpoment of minimum standards for hardwoods used in producing underground coal mine timbers. U.S. Dep. Agric. For. Serv. Res. Note NE-261. 4 p., illus.

This note presents minimum standards for raw material used in the production of sawn, split, and round timbers for the underground mining industry. The standards are based on information gathered from many mine-timber producers.

540. Timson, Floyd G.
1978. Logging residue available for mine-timber production. U.S. Dep. Agric. For. Serv. Res. Pap. NE-415. 6 p., illus.

Hardwood logging residue was examined as a source of raw material in the manufacture of sawn, split, and round timbers for use in underground coal mines. Forty-four percent of the total logging residue (residue $\geq$ 4 inches in diameter outside bark (dob), small end, and 4 feet long) from sawlog-only harvests was suitable for mine-timber production. Only 26 percent of the limbwood residue was suitable for mine timbers, but 58 percent of the bolewood ranged from less than 40 percent (beech and basswood) to 68 percent (cucumbertree).

541. Travers, Lawrence H.
1977. Perception of high-density living in Hong Kong. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 408-414.

Analysis of the Hong Kong experience of adaptation to urban living can provide insights into some of the problems that can be expected to occur in the rapidly expanding cities of the Third World. Population densities in Hong Kong are among the highest in the world, exceeding 400,000 persons per square mile in parts of Kowloon. Research based upon residence in a worker's dormitory and interviews with workers reveals a viariety of adaptive strategies employed by people to cope with the stress of the crowded urban environment. An understanding of the individual's ability to adjust to the stress of high-density living must consider the meaning of density as a concept in the culture in addition to social and cultural norms.

542. Trimble, George R., Jr.
1977. A history of the Fernow Experimental Forest and the Parsons Timber and Watershed Laboratory. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-28. 46 p., illus.

U.S. Forest Service timber-management research in West Virginia began in May 1934 when the Fernow Experimental Forest was established. Except for the war years in the 1940s, an ever-intensifying program of research has been carried out in both timber and watershed management. Lists of publications and personnel are appended.

543. Turner, Brian J., James C. Finley, and Neal P. Kingsley.
1977. How reliable are wood land owners' intentions? J. For. 75: 498-499.

Between surveys in 1970 and 1974, the proportion of Delaware landowners who said that they never planned to harvest timber remained constant (58 percent), but 35 percent of the individual owners had changed their minds about either harvesting or not harvesting. Forty-one percent were consistently opposed to harvesting, but they had only 15 percent of the state's

growing stock. Rates of change in intention and ownership suggest that eventually most of the growing stock will be harvested, although at any one time about a third of the total volume may be off the market.

544. Ungs, M., R. W. Cleary, L. Boersma, and S. Yingjajaval. 1977. The quantitative description of transfer of water and chemicals through soils. In Land as a waste management alternative. Raymond C. Loehr, ed., Ann Arbor Science Publishers, Inc. Ann Arbor, Mich. p. 109-137.

545. U.S. Forest Service. 1977. Recreational use of anthracite waste land in northeastern Pennsylvania: Suggestions for an evaluation and planning process. U.S. Dep. Agric. For. Serv. Unnumbered Misc. Publ., 112 p.

546. U. S. Forest Service. 1977. Outdoor recreation facilities in northeastern Pennsylvania 1976. U.S. Dep. Agric. For. Serv. Unnumbered Misc. Publ. (12 county booklets)

547. U.S. Forest Service. 1977. Posting in the Poconos. U.S. Dep. Agric. For. Serv. Inf. Bull. 36, 6 p.

548. U.S. Forest Service. 1978. Forest atlas of the Midwest. Robert W. Merz, compiler. U.S. Dep. Agric. For. Serv., North Cent. For. Exp. Stn., St. Paul, Minn., Northeast. For. Exp. Stn., Broomall, Pa., Coll. For., Univ. Minn., St. Paul. 48 p., illus.

Illustrates and describes the demographic, physiographic, edaphic, and climatic variables that comprise the forest environment of nine Midwestern states, and describes the important characteristics of the forests of these states.

549. Valentine, Harry T.
1978. Estimating defoliation of hardwoods using blade-petiole relations. U.S. Dep. Agric. For. Serv. Res. Pap. NE-405. 5 p.

Dimensional relations between blade weight and petiole thickness, and between blade area and petiole thickness are more useful in estimating defoliation when it occurs late in the growing season than when it occurs early in the growing season.

550. Valentine, Harry T., and Susan J. Hilton.
1977. Sampling oak foliage by the randomized-branch method. Can. J. For. Res. 7: 295-298, illus.

Foliage in mature Quercus spp. crowns was sampled by a two-phase procedure. The first phase provided estimates of the total count of leaf clusters in the tree crowns; the second-phase sample provided information about the clusters such as dry weight, surface area, and leaf count.

551. Van der Grinten, Martin, Brayton F. Wilson, and Burnell C. Fischer.
1977. Forest structure, composition, and vigor in housing developments. J. For. 75: 653-655.

552. Varma, Vishwa K.
1977. Use of the Delphi method for determining community growth goals inventory: the Nashville experience. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 432-437.

The author discusses the growth-inducing pressures on Nashville, Tennessee, describes the application of the Delphi technique to developing an inventory of the community's growth goals, and suggests that developing a list of community goals is a necessary first step toward growth management.

553. Viskanta, R., R. O. Johnson, and R. W. Bergstrom, Jr.
1977. Effect of urbanization on the thermal structure in the atmosphere. In Proc. Conf. Metrop. Phys. Evniron. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 62-76.

An unsteady two-diminsional transport model was used to study the short-term effects of urbanization and air pollution on the thermal structure in the urban atmosphere. A number of simulations for summer conditions representing the city of St. Louis were performed. The diurnal variation of the surface temperature and thermal structure are presented and the influences of various parameters are discussed.

554. Vogel, Willis G.
1977. Revegetation of surface-mined lands in the East. Proc. Soc. Am. For. 1977: 167-172.

Several species of hardwoods and pine planted 30 years ago have been reasonably successful on spoils in both the midwestern and Appalachian coal fields. Especially encouraging is the success of high-value hardwoods such as black walnut, red oak, tulip-poplar, and white pine. Many of the older strip-mined lands are also providing excellent wildlife habitat and water-based recreation. Currently, most surface mines are being revegetated with herbaceous species to provide quick erosion control. Tree planting has been discouraged by economic, legal, and social pressures. Establishment of both trees and herbaceous cover is feasible, especially by concurrent planting of tree seedlings and nonaggressive herbaceous legumes. A renewed interest in planting of woody species is needed to provide diversified uses of reclaimed land and to hasten the reestablishment of a forest ecosystem on reclaimed lands that are not consigned to other uses.

555. Vogel, Willis G., and Willie R. Curtis.
1978. Reclamation research on coal surface-mined lands in the humid East. In Reclamation of drastically disturbed lands. Am. Soc. Agron., Madison, Wis. p. 379-397.

A general overview of the results and application of some of the surface-mine reclamation research conducted on coal lands in the humid East, including revegetation, soil science, hydrology, geology, wildlife management, and engineering. Several bibliographies are cited that list most of the published information on mine reclamation research.

556. Wagar, J. Alan.
1977. Wildland recreation and resource management Proc. Wildland Recreation Conf. Banff, Alberta. Province of Alberta and Univ. Alberta. p. 11-19.

As the lead paper for the conference, outlines the nature and dimensions of wildland recreation, how other conference papers fit into a general model dealing with resource benefits, and how resource managers interface with political control of value choices.

557. Wagar, J. Alan.
1977. Resolving user conflicts. Proc. Wildland Recreation Conf. Banff, Alberta. Province of Alberta and Univ. Alberta. p. 133-145.

Reviews possibilities for technological fixes, allocation, substitution, information, and regulation as means of resolving conflicts and proposes a system of classifying and naming backcountry areas to reduce conflicts.

558. Wagar, J. Alan.
1977. Recreational carrying capacity. Proc. Wildland Recreation Conf. Banff, Alberta. Province of Alberta and Univ. Alberta. p. 168-175.

Outlines factors involved in setting use limits for recreation areas and the importance of treating each area as part of a system.

559. Wagar, J. Alan.
1977. The future and wildland recreation. Proc. Wildland Recreation Conf. Banff, Alberta. Province of Alberta and Univ. Alberta. p. 273-276.

Speculates on the effects of slowing growth, energy constraints, and likely population structure on the future of wildland recreation in Alberta.

560. Wagar, J. Alan.
1978. Why interpretation? Meeting the challenge. J. Interpretation 3(1): 6-10.

Environmental interpretation is readily justified as (1) enhancing human experiences and therefore contributing to sustained production of resource benefits and (2) helping people understand resource management alternatives, thereby contributing to responsible citizenship. Long-term prospects for interpreters are promising because the need for and potnetial benefits of interpretation are enormous and because interpreters are increasingly well trained, open to new ideas, and serious in dealing with both objectives and evaluation.

561. Walker, J. E., T. W. Gallagher, and J. Schott.
1977. Forest Damage Assessment System (FORDAS) study. U.S. Dep. Agric. For. Serv. Northeast. For. Exp. Stn. and Northeast. Area State and Priv. For. Unnumbered publ.

562. Wallin, W. B., E. G. Stern, and J. A. Johnson.
1977. Determination of flexural behavior of stringer-type pallets and skids. Va. Polytech. Inst. and State Univ. Wood Res. and Wood Constr. Lab. Pallet and Container Res. Cent. Publ. 146. 34 p.

Engineering principles are applied to the design of wooden pallets and skids with two to five stringers, in order to determine the flexural behavior of these assemblies under concentrated and uniformly distributed loads. Information is presented on principles of good pallet and skid construction. Formulae are advanced covering the strength and load-bearing capabilities of such pallets and skids.

563. Wallin, Walter B.
1977. Pallet strength computation. A simplified procedure. Va. Polytech. Inst. and State Univ. Wood Res. and Wood Constr. Lab. Pallet and Container Res. Cent. Publ. 151. 32 p.

Pallet manufacturers are continually faced with the problem of providing a product that is strong enough to perform the job, safe to use, and low in cost. This problem can be best resolved if the pallets are constructed in accordance with standard engineering principles which have been adopted for nearly all other types of wood structures. The technique provided here attempts to reduce rather complex design calculations to a series of tabulated values that may be multiplied together to select the best combinations of dimensions and materials to meet predetermined load and deflection requirements.

564. Wallner, William E.
1978. Scale insects: What the arboriculturist needs to know about them. J. Arboric. 4: 97-103, illus.

Scale insects are among the most damaging pests of shade trees and shrubs, yet they are poorly understood. This article summarizes information on the biology, feeding mechanism in relation to host damage, and control of the major scale groups.

565. Walters, Russell S.
1978. Vacuum transfer system increases sugar maple sap yield. U.S. Dep. Agric. Res. Note NE-264. 4 p., illus.

Yields of sugar maple sap collected from three plastic pipeline systems by gravity, vacuum pump, and a vacuum pump with a transfer tank were compared during 2 years in northern Vermont. The transfer system yielded 27 percent more sap one year and 17 percent more the next year. Higher vacuum levels at the tapholes were observed in the transfer systems.

566. Walters, Russell S.
1978. Tapholes drilled into frozen sugar maples close slowly. U.S. Dep. Agric. For. Serv. Res. Note NE-265. 4 p., illus.

Tapholes drilled into frozen maple tissues remain open longer than tapholes drilled into trees that have not frozen. Taphole closure was not affected by the speed of the tapper drill bit.

567. Walters, Russell S.
1978. Coniferous understory influences sugar maple (Acer saccharum Marsh.) sap production. U.S. Dep. Agric. For. Serv. Res. Pap. NE-398. 5 p., illus.

Sap and maple syrup production increased after a coniferous understory was removed from a sugarbush in northwest Vermont. These increases were 14 to 17 percent, respectively, and became apparent the 6th year after treatment.

568. Walters, Russell S., and Alex L. Shigo.
1978. Discolouration and decay associated with paraformaldehyde-treated tapholes in sugar maple. Can. J. For. Res. 8: 54-60, illus.

More decay (higher incidence and longer columns) was associated with sugar maple tapholes treated with paraformaldehyde than with control tapholes. This first became apparent 20 months after treatment. Discolored columns associated with pill-treated tapholes were longer than those associated with control tapholes for the first 8 months. After that time there was no statistically significant differences between column lengths associated with pill-treated and control tapholes. Cambial dieback occurred adjacent to many tapholes but there was no significant difference in closure rates of treated and control tapholes. The results indicate that repeated use of paraformaldehyde will lead to rapid development of decay in sugar maple trees.

569. Walters, Russell S., and Harry W. Yawney.
1978. Plastic tubing and maple syrup quality. U.S. Dep. Agric. For. Serv. Res. Pap. NE-409. 9 p., illus.

Daily maple syrup samples processed from sap collected using an improperly or carelessly installed plastic pipeline were more variable in grade and often of a lower grade than syrup from sap collected using a properly installed pipeline. Syrup samples of equal grade were produced from sap collected by the properly installed pipeline and by buckets.

570. Wargo, Philip M.
1977. Wound closure in sugar maple: Adverse effects of defoliation. Can. J. For. Res. 7: 410-414.

Twenty-three sugar maple trees that were defoliated by hand for 3 consecutive years and nine undefoliated trees were wounded with a drill bit in March 1974. After two full growing seasons, wound areas on defoliated trees were larger than those on undefoliated trees because of a more severe response by defoliated trees to wounding, and because of slower healing caused by smaller radial increment. More tissue died around the wounds on defoliated trees. There was no significant increase in internal discoloration, but decay was found in two defoliated trees. In undefoliated trees, wound closure was highly correlated with annual growth increment and resistance to pulsed electric current (ER). In defoliated trees, wound area was highly correlated with starch content of the roots.

571. Wargo, Philip M.
1977. *Armillariella mellea* and *Agrilus bilineatus* and mortality of defoliated oak trees. For. Sci. 23: 485-492, illus.

Dead, recently dead, dying, and living trees in areas defoliated by the gypsy moth, *Lymantria dispar* were examined for the presence of the shoe-string fungus *Armillariella mellea* and the two-lined chestnut borer *Agrilus bilineatus*. Root systems were excavated with a front-end loader. *A. mellea* was established in the

roots of one-third of the living trees examined. Colonization on trees with healthy crowns was limited to one or several small roots. On trees with half-dead crowns, the fungus had extensively colonized the roots and on many trees was present at the root collar. Both A. mellea and A. bilineatus were present in dead, recently dead, and dying trees. The roots of most of the recently dead or dying trees were extensively colonized by A. mellea, even though the fungus was not visible at the root collar. It is proposed that oak mortality results from an interaction of A. mellea and A. bilineatus.

572. Wargo, Philip M.
1978. Correlations of leaf area with length and width measurements of leaves of black oak, white oak, and sugar maple. U.S. Dep. Agric. For. Serv. Res. Note NE-256. 3 p.

Correlations of leaf area with length, width, and length times width of leaves of black oak, white oak, and sugar maple were determined to see if length and/or width could be used as accurate estimators of leaf area. The correlation of length times width with leaf area was high ($r > +.95$) for all three species. The linear equation $Y = a + bX$, where $X$ = length times width, can be used to estimate leaf area where it is not possible or practical to make actual area measurements.

573. Wargo, Philip M.
1978. Defoliation by the gypsy moth: How it hurts your tree. U.S. Dep. Agric. Gypsy Moth Handb., Home and Garden Bull. No. 223. 15 p.

Defoliation can be harmful to trees under certain conditions. The effects of defoliation depend on how much foliage was eaten, if the tree refoliated, how many years in succession the tree was defoliated, when during the growing season (early, middle, or late) defoliation occurred, what the weather conditions were after defoliation, if disease organisms and other insects attacked the tree, and how healthy or vigorous the tree was before defoliation.

574. Wargo, Philip M.
1978. Insects have defoliated my tree--now what's going to happen? J. Arboric. 4(8): 169-175, illus.

The effects of defoliation are not dependent on defoliation alone but on a complex interaction of many factors. The major influencing factors of severity, frequency, and timing of defoliation; growing conditions; secondary organisms; and tree vigor are discussed. Some of the adverse effects of defoliation are described and recommendations for preventing or lessening these effects are given.

575. Wartluft, Jeffrey L.
1977. Weights of small Appalachian hardwood trees and components. U.S. Dep. Agric. For. Serv. Res. Pap. NE-366. 4 p., illus.

Whole-tree weights, green and oven-dry, are shown in tables for Appalachian hardwood trees 1 to 10 inches dbh. Weights are also divided into tree portions greater than 3 inches and less than or equal to 3 inches in diameter. Information on species, moisture content, and percent bark accompany the weights. And metric conversions are provided.

576. Wells, O. O., P. E. Barnett, H. J. Derr, D. T. Funk, Timothy La Farge, E. R. Lawson, and Silas Little.
1978. Shortleaf X slash pine hybrids outperform parents in parts of the Southeast. South. J. Appl. For. 2(1): 28-32.

Hybrids were tested against their parent species for 10 years at 8 locations from New Jersey and Ohio to Louisiana. Certain hybrids performed better than either parent species in Georgia, Alabama, and Arkansas. However, shortleaf pine performed better than the hybrids in New Jersey and Ohio.

577. Wendel, G. W.
1977. Longevity of black cherry, wild grape, and sassafras seed in the forest floor. U.S. Dep. Agric. For. Serv. Res. Pap. NE-375. 6 p., illus.

The results of this study show that (1) black cherry seed remains viable in the forest floor for 3 years, with a small amount of seed germinating after 4 to 5 years; (2) sassafras seed remains viable for 5 years in the forest floor, and (3) some wild grape seed retains its viability for at least 8 years. These results are important to the forest manager in setting up harvest schedules and controlling unwanted species in the new stand.

578. Wendel, G. W., and J. N. Kochenderfer.
1978. Damage to residual hardwood stands caused by cable yarding with a standing skyline. South. J. Appl. For. 2(4): 121-125, illus.

Yarding logs with a standing skyline cable system in a partially-cut hardwood stand injured or destroyed about 7 percent of the residual stand--stems larger than 1.0 inch dbh. One tree per acre was abraded, 16 per acre were skinned (sapwood exposed), 2 per acre suffered root damage, and 15 per acre were destroyed. Results of this study were compared with published reports on tree injuries caused by cable yarding and skidding with crawler tractors and rubber-tired skidders in the eastern and western United States.

579. Whelan, J. B., K. I. Morris, R. F. Harlow, and H. S. Crawford.
1976. The bioenergetic approach to forest range management. Proc. 10th Northeast Deer Study Group, Yarmouth, Nova Scotia, Canada. September 1974. p. 28-43.

Dry matter production and digestible energy were determined on composite diets comprised of "key" deer food plants, collected during four seasons in a mixed oak-pine forest type in southwest Virginia. The ratios of total digestible energy avaiable in "key" forages to the energy required by the estimated deer population at a 50 percent forage utilization rate were 1.30, 2.98, 0.89, 0.91, and 0.56 (kcal/ha/da) for the spring flush, spring, summer, fall, and winter, respectively. These energy conversion ratios indicate the seasonal potential of the forest type to support the estimated population of 1 deer per 16.4 ha. A seasonal forage utilization rate

of 50 percent appears adequate for meeting the daily energy needs of the deer population during the spring flush and spring periods, however the 50 percent rate appears marginal for the summer and fall seasons and was inadequate for the winter season.

580. Wilkinson, Ronald C.
1977. Height growth performance of white spruce (Picea glauca (Moench) Voss) provenances in central Maine. Northeast. For. Tree Improv. Conf. Proc. 25: 87-93.

Height growth measurements were made in a range-wide geographic seed source test of white spruce on the Penobscot Experimental Forest, Bradley, Maine, after 10 and 15 growing seasons. After 15 years in the field, 14 of 24 seed-sources exceeded the plantation mean in height growth. Most of the fastest growing seed-sources are from the southeastern part of the range of white spruce. Trees from the more northern sources were poorly adapted to the planting site and had slow overall growth. The local source exceeded plantation mean height growth by 15 percent. Six other seed sources exceeded the mean by 18 to 32 percent. The six tallest seed-sources after 15 years were also the tallest at 10 years and among the 9 tallest at 5 years. Two sources, one from Beachburg, Ontario, and the other from north-central Michican, were 12 and 15 percent faster growing than the local source. Significant improvement could be made by simply introducing seed from these two sources into the region represented by the test plantation site.

581. Wilkinson, Ronald C.
1977. Inheritance of budbreak and correlation with early height growth in white spruce (Picea glauca) from New England. U.S. Dep. Agric. For. Ser. Res. Pap. NE-391. 5 p.

Variation in budbreak date among 37 half-sib families of white spruce in a replicated one-parent progeny test plantation in southern Maine was only 5 days. Differences in the mean data of budbreak between years were greater than those between families, but the genetic correlation between date of budbreak in different years was .661. Heritability estimates ranged from .228 to

.814, depending on the year and method of calculation. In each of 2 years, heritabilities estimated for family selection were higher than those for mass selection of individual trees in the planation.

582. Williamson, D., J. Fabos, and R. Brush.
1977. The visual screening potential of forest vegetation. Landscape Archit. Q. 68(1): 44.

583. Wilson, R. W., and G. A. Fontaine.
1978. Gypsy moth egg-mass sampling with fixed and variable-radius plots. U.S. Dep. Agric. Handb. 523.

584. Woch, W.
1976. Cell events in cambium connected with the formation and existence of a whirled cell arrangement. Acta Soc. Bot. Pol. 45: 313-326.

Tumorous areas in otherwise normal wood of Picea and other conifers result from local areas of cambium having a much higher than normal rate of non-randomly oriented anticlinal cell divisions and also a very high rate of intrusive growth. This study provides a method of pinpointing the initial event in time and space. Thus the cause of tumor induction may be deduced.

585. Wolf, Charles H.
1977. Wage differentials among Appalachian sawmills. U.S. Dep. Agric. For. Serv. Res. Note NE-237. 5 p.

Wage differences among Appalachian sawmills were investigated, using multiple-regression analysis. Wages and fringe benefits were found to vary with type of product sawed, education of the work force, distance to urban areas, general wage levels, and use of collective-bargaining agreements between management and labor.

586. Wolf, Charles H.
1977. Job-quitting at Appalachian sawmills. U.S. Dep. Agric. For. Serv. Res. Pap. NE-369. 10 p., illus.

The author investigated the rate, causes, and control of employee turnover in Appalachian sawmills. In the typical mill surveyed, the number of workers who quit annually was about equal to the mill's average employment. Variation in quit rates was associated with the age of the workers, the wages and number of holidays they received, and the general wage level and unemployment rate in local labor markets.

587. Wolf, Charles H., and Jean W. Nolley.
1977. Changes in the logging labor force. U.S. Dep. Agric. For. Serv. Res. Pap. NE-359. 7 p., illus.

Employment in the logging industry dropped 28 percent between 1950 and 1970, while output of industrial roundwood increased 31 percent. Today's loggers are older, better educated, and more skilled. A large proportion are self-employed, many work less than a full year, and a substantial number have incomes below the poverty level. Mechanization of timber harvesting will continue to affect the size and makeup of the labor force.

588. Wollam, John D., William G. Yendol, and Franklin B. Lewis.
1978. Evaluation of aerially-applied nuclear polyhedrosis virus for suppression of the gypsy moth, Lymantria dispar L. U.S. Dep. Agric. For. Serv. Res. Pap. NE-396. 8 p. illus.

Single and double applications of the nuclear polyhedrosis virus of Lymantria dispar resulted in foliage protection, population reduction, and increased numbers of virus-infected hosts. Second generation larval emergence was significantly lower in treated areas than in untreated populations.

589. Yap, D.
1977. A preliminary investigation of the nocturnal temperature structure above the city of Edmonton, Alberta. In Proc. Conf. Metrop. Phys. Environ. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-25. p. 77-87.

Information about the nocturnal temperature structure over Edmonton, Alberta. Observations of the temperature fields, including two- and three-dimensional forms of the nocturnal heat island, were obtained from minisonde ascents, an instrumented helicopter, and towers during a 3-week urban air-pollution field study. Results show that urban-induced temperature modification is typically in the lowest 100 m above ground. Along the direction of the prevailing wind, there is a progressive modification of very stable upwind air as it flows toward the city center, the urban air being less stable. Implications of these observed features on urban air pollution are discussed.

590. Yawney, Harry W.
1977. Why vacuum pumping increases sap production. Natl. Maple Syrup Dig. 16(1): 20-23.

Under normal conditions, sap from sugar maple trees flows from tapholes when pressures inside the trees are higher than atmospheric pressure. Vacuum pumping has the effect of lowering the atmospheric pressure within a closed plastic tubing system. As a result, vacuum pumps will produce sap on days when sap ordinarily would not run, and also increase sapflow during normal flow periods.

☆U.S. GOVERNMENT PRINTING OFFICE: 1979 605 294 612

Northeastern Forest Experiment Station.
1979. 1977-1978 Report. Northeast. For. Exp. Stn., Broomall, Pa.
206 p. (USDA For. Serv. Gen. Tech. Rep. NE-50)

A summary report on highlights of research activities and accomplishments of the Experiment Station in 1977 and 1978, including an annotated list of publications.

(74/75) : 945.4 : (047.1)

Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories and research units are maintained at:

- Beltsville, Maryland.
- Berea, Kentucky, in cooperation with Berea College.
- Burlington, Vermont, in cooperation with the University of Vermont.
- Delaware, Ohio.
- Durham, New Hampshire, in cooperation with the University of New Hampshire.
- Hamden, Connecticut, in cooperation with Yale University.
- Kingston, Pennsylvania.
- Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
- Orono, Maine, in cooperation with the University of Maine, Orono.
- Parsons, West Virginia.
- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- University Park, Pennsylvania.
- Warren, Pennsylvania.

by Stanford L. Arner
and Donald W. Seegrist

UNIVERSITY LIBRARY
MAY 3 1979
TECH. S

DOCUMENT
REPOSITORY ITEM

# A COMPUTER PROGRAM

## for the Maximum Likelihood Estimator of the General Multivariate Linear Model with Correlated Errors

**FOREST SERVICE GENERAL TECHNICAL REPORT NE-51**
**1979**
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
370 REED ROAD, BROOMALL, PA. 19008

## The Authors

STANFORD L. ARNER joined the Northeastern Forest Experiment Station in 1966 and has served as a computer programmer and biological statistician with the Station's Biometrics Group, located in Broomall, PA. He received a B. S. degree in forest science in 1966 from the Pennsylvania State University, and a M. S. degree in 1971 from the School of Forest Resources at Pennsylvania State University.

DONALD W. SEEGRIST joined the Northeastern Forest Experiment Station in 1968 and currently is Leader of the Station's Biometrics Group. He received a B. S. degree in zoology in 1953 from George Washington University, and M. S. and Ph. D. degrees in zoology in 1959 and 1965, respectively, from the University of California, Berkeley. He joined the Forest Service in 1963 as a biological statistician with the Pacific Southwest Forest and Range Experiment Station at Berkeley.

MANUSCRIPT RECEIVED FOR PUBLICATION 30 NOVEMBER 1978

# A COMPUTER PROGRAM

## for the Maximum Likelihood Estimator of the General Multivariate Linear Model with Correlated Errors


### Abstract

This report describes a computer program that obtains maximum likelihood estimates of the parameters for a general linear model with correlated observations. The variates can be a set of different types of variates, repeated measurement on the same variate, or combinations of repeated measurements and different variates. A forest growth and yield model describing repeated measurement of plot volume and basal area is presented as an example.

IN THIS REPORT we describe a computer program that obtains maximum likelihood estimates of the parameters for a general multivariate linear model with two or more correlated observations. The variates can be a set of different types of variates, repeated measurements on the same variate, or combinations of repeated measurements and different variates.

We present, as an example, the growth and yield model described by Clutter (1963). This model uses recursive simultaneous equations to describe plot volume and basal area where the values are measured repeatedly on the same plot.

The general multivariate linear model for p correlated measurements on each of n plots can be written

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\epsilon} \qquad (1)$$

where $\mathbf{y}' = (\mathbf{y}'_1, \mathbf{y}'_2, \ldots, \mathbf{y}'_p)$

$\mathbf{X}' = (\mathbf{X}'_1, \mathbf{X}'_2, \ldots, \mathbf{X}'_p)$

and $\mathbf{y}'_i = (y_{i1}, \ldots, y_{in})$

$\mathbf{X}'_i = (\mathbf{x}'_{i1}, \ldots, \mathbf{x}'_{in})$

$\mathbf{x}_{ij} = (x_{ij1}, \ldots, x_{ijq})$.

The element $y_{ij}$ is the observed value of variate $Y_i$ on plot j and $x_{ijk}$ is the observed value of the $k^{th}$ independent variable associated with $Y_i$ on plot j.

We assume that the vectors of observations for the n plots are mutually independent and that the p observations for each plot have the covariance matrix $\boldsymbol{\Sigma}$. Therefore, the covariance matrix for y can be written as $\boldsymbol{\Psi} = \boldsymbol{\Sigma} \times \mathbf{I}$, where X represents the Kronecker product. The order of $\boldsymbol{\Sigma}$ is p, and $\mathbf{I}$ is the identity matrix of order n.

Due to correlation among the observations, the ordinary least squares procedure cannot be used to solve the system (1) for estimates of $\boldsymbol{\beta}$. Therefore, we developed a computer program to obtain maximum likelihood estimates for $\boldsymbol{\beta}$ and $\boldsymbol{\Sigma}$.

The program maximizes the logarithm of the likelihood function of y;

$$L = -np/2 \ln(2\Pi) + n/2|\boldsymbol{\Sigma}^{-1}| - 1/2\, Q \qquad (2)$$

where $Q = (\mathbf{y} - \mathbf{X}\boldsymbol{\beta})' \boldsymbol{\Psi}^{-1} (\mathbf{y} - \mathbf{X}\boldsymbol{\beta})$

and $|\boldsymbol{\Sigma}^{-1}|$ denotes the determinant of matrix $\boldsymbol{\Sigma}^{-1}$.

For the maximization of L, we require the first and second derivatives of L with respect to $\boldsymbol{\beta}$ and $\boldsymbol{\Sigma}^{-1}$. Denote the tu element of $\boldsymbol{\Sigma}^{-1}$ as $\sigma^{tu}$. The required derivatives are presented in a form convenient for computation. Their derivation can be found in Seegrist and Arner (1978).

The first derivatives can be written

$$\frac{\partial L}{\partial \boldsymbol{\beta}} = \sum_t \sigma^{tt}(\mathbf{X}'_t\mathbf{y}_t - \mathbf{X}'_t\mathbf{X}_t\boldsymbol{\beta}) + \sum_t \sum_{u>t} \sigma^{tu}[\mathbf{X}'_t\mathbf{y}_u + \mathbf{X}'_u\mathbf{y}_t - (\mathbf{X}'_t\mathbf{X}_u + \mathbf{X}'_u\mathbf{X}_t)\boldsymbol{\beta}] \tag{3}$$

$$\frac{\partial L}{\partial \sigma^{tt}} = \frac{n}{2}\sigma_{tt} - \frac{1}{2}(\mathbf{y}'_t\mathbf{y}_t - 2\boldsymbol{\beta}'\mathbf{X}'_t\mathbf{y}_t + \boldsymbol{\beta}'\mathbf{X}'_t\mathbf{X}_t\boldsymbol{\beta})$$

$$\frac{\partial L}{\partial \sigma^{tu}} = n\sigma_{tu} - (\mathbf{y}'_t\mathbf{y}_u - \boldsymbol{\beta}'\mathbf{X}'_t\mathbf{y}_u - \boldsymbol{\beta}'\mathbf{X}'_u\mathbf{y}_t + \boldsymbol{\beta}'\mathbf{X}'_t\mathbf{X}_u\boldsymbol{\beta}).$$

The second order derivatives are

$$\frac{\partial^2 L}{\partial \boldsymbol{\beta}\partial \boldsymbol{\beta}} = -\sum_t \sigma^{tt}\mathbf{X}'_t\mathbf{X}_t - \sum_t \sum_{t<u} \sigma^{tu}(\mathbf{X}'_t\mathbf{X}_u + \mathbf{X}'_u\mathbf{X}_t) \tag{4}$$

$$\frac{\partial^2 L}{\partial \sigma^{rs}\sigma^{tu}} = -n(\sigma_{tr}\sigma_{su} + \sigma_{ts}\sigma_{ru})$$

$$\frac{\partial^2 L}{\partial \sigma^{rs}\sigma^{tt}} = -n\,\sigma_{tr}\sigma_{st}$$

$$\frac{\partial^2 L}{\partial \sigma^{rr}\sigma^{tu}} = -n\,\sigma_{tr}\sigma_{ru}$$

$$\frac{\partial^2 L}{\partial \sigma^{rr}\sigma^{tt}} = -\frac{n}{2}\sigma_{tr}\sigma_{tr}$$

$$\frac{\partial^2 L}{\partial \boldsymbol{\beta}\partial \sigma^{tu}} = \mathbf{X}'_t\mathbf{y}_u + \mathbf{X}'_u\mathbf{y}_t - (\mathbf{X}'_t\mathbf{X}_u + \mathbf{X}'_u\mathbf{X}_t)\boldsymbol{\beta} \qquad \text{if } t \neq u$$

$$= \mathbf{X}'_t\mathbf{y}_t - \mathbf{X}'_t\mathbf{X}_t\boldsymbol{\beta} \qquad \text{if } t = u.$$

## CALCULATING THE MAXIMUM LIKELIHOOD ESTIMATES

The likelihood equations are nonlinear and have to be solved by iterative procedures. The initial estimates of the model parameters that we use are the ordinary least squares estimates $\hat{\boldsymbol{\beta}}_o = (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{y}$, and the estimated variances and covariances based on $\hat{\boldsymbol{\beta}}_o$

$$\hat{\sigma}_{tuo} = (\mathbf{y}'_t\mathbf{y}_u - \hat{\boldsymbol{\beta}}'_o\mathbf{X}'_t\mathbf{y}_u - \hat{\boldsymbol{\beta}}'_o\mathbf{X}'_u\mathbf{y}_t + \hat{\boldsymbol{\beta}}'_o\mathbf{X}'_t\mathbf{X}_u\hat{\boldsymbol{\beta}}_o)/N.$$

The program uses three procedures for solving the likelihood equations; (1) Newton-Raphson; (2) Fisher scoring; and (3) the iterated Aitken procedure. Different iterative procedures are needed because one of the procedures may not converge to a solution; and the different procedures converge at different rates. The method of determining which procedure to use at each iteration is: if the change in L is less than a specified value at the preceeding iteration, the Newton-Raphson procedure is used; if the change in L is greater than the specified value, or if the Newton-Raphson procedure does not work, the Fisher scoring method is used. Finally, the iterated Aitken method is used if both Newton-Raphson and Fisher scoring procedures fail to work. These two procedures may not work at a particular iteration because of an ill-conditioned matrix of second derivatives, an ill-conditioned estimate of $\boldsymbol{\Sigma}$, or a decrease in the value of the likelihood function when evaluated at the new estimates.

The three methods of solving the likelihood equations are based on calculating a vector of increments ($\boldsymbol{\Delta}$) to the vector of parameter estimates ($\hat{\boldsymbol{\theta}}$). The iterated parameter estimates are $\hat{\boldsymbol{\theta}}_i = \hat{\boldsymbol{\theta}}_{i-1} + \boldsymbol{\Delta}_i$.

The vector of increments $\boldsymbol{\Delta}$ for the Newton-Raphson procedure is

$$\boldsymbol{\Delta}_i = -\begin{bmatrix} \dfrac{\partial^2 L}{\partial \boldsymbol{\beta}\partial \boldsymbol{\beta}} & \dfrac{\partial^2 L}{\partial \boldsymbol{\beta}\partial \boldsymbol{\Sigma}^{-1}} \\ \dfrac{\partial^2 L}{\partial \boldsymbol{\Sigma}^{-1}\partial \boldsymbol{\beta}} & \dfrac{\partial^2 L}{\partial \boldsymbol{\Sigma}^{-1}\partial \boldsymbol{\Sigma}^{-1}} \end{bmatrix}^{-1}_{(i-1)} \begin{bmatrix} \dfrac{\partial L}{\partial \boldsymbol{\beta}} \\ \dfrac{\partial L}{\partial \boldsymbol{\Sigma}^{-1}} \end{bmatrix}_{(i-1)} \tag{5}$$

The first matrix on the right side of (5) is the inverse of the matrix of second derivatives of the likelihood function and the second matrix is the vector of first derivatives. The notation $[\ ]_{i-1}$ indicates that the elements of the vector of first derivatives (3)

and the elements of the matrix of second derivatives (4) are evaluated at $\hat{\boldsymbol{\theta}}_{i-1}$. $\partial L/\partial \boldsymbol{\Sigma}^{-1}$ denotes a vector whose $tu^{th}$ element is $\partial L/\partial \sigma^{tu}$, $\partial^2 L/\partial \boldsymbol{\beta} \partial \boldsymbol{\Sigma}^{-1}$ is a matrix whose $tu^{th}$ column is the vector $\partial^2 L/\partial \boldsymbol{\beta} \partial \sigma^{tu}$, and $\partial^2 L/\partial \boldsymbol{\Sigma}^{-1} \partial \boldsymbol{\Sigma}^{-1}$ is a matrix whose element in row (r,s) and column (t,u) is $\partial^2 L/\partial \sigma^{rs} \partial \sigma^{tu}$, for $1 \leq r \leq s \leq 1, \ldots, p, 1 \leq t \leq u = 1, \ldots, p$.

The vector of increments for the Fisher scoring procedure is

$$\boldsymbol{\Delta}_i = - \begin{bmatrix} \dfrac{\partial^2 L}{\partial \boldsymbol{\beta} \partial \boldsymbol{\beta}} & 0 \\ 0 & \dfrac{\partial^2 L}{\partial \boldsymbol{\Sigma}^{-1} \partial \boldsymbol{\Sigma}^{-1}} \end{bmatrix}_{(i-1)}^{-1} \begin{bmatrix} \dfrac{\partial L}{\partial \boldsymbol{\beta}} \\ \dfrac{\partial L}{\partial \boldsymbol{\Sigma}^{-1}} \end{bmatrix}_{(i-1)} \quad (6)$$

The first step of the iterated Aitken proceduce is to calculate the increment to the vector of regression coefficients ($\hat{\boldsymbol{\beta}}$) which is

$$\boldsymbol{\Delta}(\hat{\boldsymbol{\beta}}_i) = - \left[ \frac{\partial^2 L}{\partial \boldsymbol{\beta} \partial \boldsymbol{\beta}} \right]_{(i-1)}^{-1} \left[ \frac{\partial L}{\partial \boldsymbol{\beta}} \right]_{(i-1)}$$

The iterated estimate of the vector of regression coefficients is $\hat{\boldsymbol{\beta}}_i = \hat{\boldsymbol{\beta}}_{i-1} + \boldsymbol{\Delta}(\hat{\boldsymbol{\beta}}_i)$. It can be shown that $\hat{\boldsymbol{\beta}}_i$ is the generalized least squares estimator of $\boldsymbol{\beta}$ evaluated at $\hat{\boldsymbol{\Sigma}}_{i-1}$. The iterated variance and covariance estimates are

$$\hat{\sigma}_{tui} = (\mathbf{y}'_t \mathbf{y}_u - \hat{\boldsymbol{\beta}}'_i (\mathbf{X}'_t \mathbf{y}_u + \mathbf{X}'_u \mathbf{y}_t) + \hat{\boldsymbol{\beta}}'_i \mathbf{X}'_t \mathbf{X}_u \hat{\boldsymbol{\beta}}_i)/N.$$

The iterations are terminated when $L_i - L_{i-1} < \epsilon$ where $\epsilon$ is a small predetermined value, and $L_i$ is the logarithm of the likelihood function evaluated at $\hat{\boldsymbol{\theta}}_i$.

The major computational problem is the matrix inversion required for the calculation of $\boldsymbol{\Delta}_i$. For the Newton-Raphson procedure, the matrix of second derivatives evaluated at $\hat{\boldsymbol{\theta}}_{i-1}$ may be singular. We also found that, when the residuals are highly correlated, the matrix of second derivatives with respect to the elements of $\boldsymbol{\Sigma}^{-1}$ is ill-conditioned. This second problem was alleviated when we noticed that the inverse of $\partial^2 L/\partial \boldsymbol{\Sigma}^{-1} \partial \boldsymbol{\Sigma}^{-1}$ could be calculated directly from the estimates of $\sigma^{ij}$ calculated at the previous iteration.

Denote $\partial^2 L/\partial \boldsymbol{\Sigma}^{-1} \partial \boldsymbol{\Sigma}^{-1}$ as $\boldsymbol{\Lambda}$. We found that the element in row (r,s) and column (t,u) of the inverse of $\boldsymbol{\Lambda}$ is

$$\Lambda^{(rs),(tu)} = -\frac{1}{n} (\sigma^{tr} \sigma^{su} + \sigma^{ts} \sigma^{ru}).$$

Thus, the Fisher scoring procedure requires only one matrix inversion, the qxq matrix of second derivatives with respect to $\boldsymbol{\beta}$. If the matrix of second derivatives needed for the Newton-Raphson procedure is negative definite, it's inverse can be calculated with one more inversion of a matrix of order q by using definitions of the inverse of a partitioned matrix.

The point at which an iteration should be started with the Newton-Raphson procedure has not been determined. In their procedure for variance component estimation, Jennrich and Sampson (1976) use the scoring algorithm whenever the change in L is greater than 1.0. On the data sets we have worked with, we have found that the Newton-Raphson procedure converges more rapidly than the other two procedures when the full matrix of second derivatives can be inverted. The point at which this occurs seems a characteristic of each data set.

When a solution is obtained by a particular algorithm, but the change in L is negative, the program switches to a partial stepping procedure similar to that suggested by Jennrich and Sampson (1976). At each step, $\boldsymbol{\Delta}$ is divided by 4 and new estimates are obtained. The partial stepping is terminated at the first step which increases L.

## PROGRAM INFORMATION

The program arrays are dimensioned for a maximum p of 10 and a maximum q of 12. If larger problems are encountered, the size of the appropriate arrays should be changed. Instructions for doing this are found in the comments section at the beginning of the program. The control card instructions are also located here, as well as in Appendix I.

When a matrix cannot be inverted, the program terminates with an error message. Appendix I contains an explanation of these messages.

The program output includes the estimates of $\boldsymbol{\beta}$, $\boldsymbol{\Sigma}$, $|\hat{\boldsymbol{\Sigma}}|$, the value of L evaluated at these estimates, and the inverse of the negative of the matrix of second derivatives with respect

to $\boldsymbol{\beta}$ and $\boldsymbol{\Sigma}$. The elements of these matrices can be used as estimates of the variances and covariances of $\hat{\boldsymbol{\beta}}$ and $\hat{\boldsymbol{\Sigma}}$.

The value of L can be used to set up likelihood ratio tests to determine whether some of the independent variables can be dropped from the model. If $L_\Omega$ is the value of the log likelihood function under the full model, and $L_\omega$ is the value obtained with the restricted model (deletion of a portion of $\boldsymbol{\beta}$ of length $q_1$), then $-2\ (L_\omega - L_\Omega)$ is asymptotically distributed as $\chi^2$ with $q_1$ degrees of freedom.

The estimates of $\boldsymbol{\beta}$ and $\boldsymbol{\Sigma}$ are both printed and punched. The punched cards can be read as starting values for further iterations (see program control information).

## PROGRAM APPLICATION

The program was initially developed to obtain solutions to the forest growth and yield functions as described by Sullivan and Clutter (1972) when there are more than two repeated measurements per plot. The model and procedure presented here are more general, however. With proper construction of the data, the program can obtain solutions to the usual multivariate linear regression model as well as solutions to some systems of equations, where the dependent variables are combinations of repeated measurements and measurements on several correlated variates. Note that the $\mathbf{X}_i$ can be combinations of experimental design variables and covariates and need not be the same for the different $\mathbf{y}_i$.

A sample problem is presented in Appendix II for 3 repeated measurements on each of 22 fixed plots. We use Clutter's (1963) growth and yield model to describe plot volume and basal area. The equations can be written as

$$E(\ln V_{ti}) = \beta_0 + \beta_1 S_i + \beta_2 A_{ti}^{-1} + \beta_3 \ln B_{ti}$$

$$E(\ln B_{ti}) = A_{1i}A_{ti}^{-1} \ln B_{1i} + \alpha_1(1 - A_{1i}A_{ti}^{-1}) + \alpha_2(1 - A_{1i}A_{ti}^{-1})S_i$$

where $V_{ti}$ = cubic foot volume per acre on the $i^{th}$ plot at time t,
$S_i$ = site index of $i^{th}$ plot (in feet),
$A_{ti}$ = stand age of $i^{th}$ plot at time t,
and $B_{ti}$ = basal area per acre of the $i^{th}$ plot at time t (in square feet).

We consider stand ages ($A_t$) and initial basal area ($B_1$) as design variables. Note that the basal area equation for time 1 is an identity, while the coefficient for $A_{1i}/A_{ti}$ $\ln B_{1i}$ in the basal area equation for the second and third remeasurement periods is always 1. To obtain the computing form for the data, we delete the first basal area equation and subtract $A_1A_t^{-1}$ $\ln B_1$ from both sides of the $t^{th}$ basal area equation for t = 2, 3.

Appendix II contains a partial listing of the sample data and the control cards required to run the program with the data. The first four fields of the sample data cards contain identification information only, and are not used by the program. The values are plot number, measurement period, equation type, and variate number.

The data for the five equations for each plot are together. The first three cards have the data for the three volume equations, the last two cards have the data for the basal area equations for time 2 and 3. The data on the data cards are the values of the variables defined as shown in Table 1.

**Table 1.—Data layout**

| Y | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ |
|---|---|---|---|---|---|---|
| $\ln V_1$ | 1.0 | S | $A_1^{-1}$ | $\ln B_1$ | 0.0 | 0.0 |
| $\ln V_2$ | 1.0 | S | $A_2^{-1}$ | $\ln B_2$ | 0.0 | 0.0 |
| $\ln V_3$ | 1.0 | S | $A_3^{-1}$ | $\ln B_3$ | 0.0 | 0.0 |
| $\ln B_2^*$ | 0.0 | 0.0 | 0.0 | 0.0 | $1 - A_1A_2^{-1}$ | $(1 - A_1A_2^{-1})S$ |
| $\ln B_3^*$ | 0.0 | 0.0 | 0.0 | 0.0 | $1 - A_1A_3^{-1}$ | $(1 - A_1A_3^{-1})S$ |

where $\ln B_t^* = \ln B_t - A_1A_t^{-1}\ln B_1$.

Arner, Stanford L., and Donald W. Seegrist
1979. **A computer program for the maximum likelihood estimator of the general multivariate linear model with correlated errors.** Northeast. For. Exp. Stn., Broomall, PA. 10 p. (U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-51)

Description of a computer program that obtains maximum likelihood estimates of the parameters for a general linear model with correlated errors. The variates can be a set of different types of variates, repeated measurement on the same variate, or combinations of repeated measurements and different variates. A forest growth and yield model describing repeated measurement of plot volume and basal area is presented as an example.

[853:525.1]—051.5

**Keywords:** Growth and Yield

Arner, Stanford L., and Donald W. Seegrist
1979. **A computer program for the maximum likelihood estimator of the general multivariate linear model with correlated errors.** Northeast. For. Exp. Stn., Broomall, PA. 10 p. (U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-51)

Description of a computer program that obtains maximum likelihood estimates of the parameters for a general linear model with correlated errors. The variates can be a set of different types of variates, repeated measurement on the same variate, or combinations of repeated measurements and different variates. A forest growth and yield model describing repeated measurement of plot volume and basal area is presented as an example.

[853:525.1]—051.5

**Keywords:** Growth and Yield

Arner, Stanford L., and Donald W. Seegrist
1979. **A computer program for the maximum likelihood estimator of the general multivariate linear model with correlated errors.** Northeast. For. Exp. Stn., Broomall, PA.
10 p. (U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-51)

Description of a computer program that obtains maximum likelihood estimates of the parameters for a general linear model with correlated errors. The variates can be a set of different types of variates, repeated measurement on the same variate, or combinations of repeated measurements and different variates. A forest growth and yield model describing repeated measurement of plot volume and basal area is presented as an example.

[853:525.1]—051.5

**Keywords:** Growth and Yield

Arner, Stanford L., and Donald W. Seegrist
1979. **A computer program for the maximum likelihood estimator of the general multivariate linear model with correlated errors.** Northeast. For. Exp. Stn., Broomall, PA.
10 p. (U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-51)

Description of a computer program that obtains maximum likelihood estimates of the parameters for a general linear model with correlated errors. The variates can be a set of different types of variates, repeated measurement on the same variate, or combinations of repeated measurements and different variates. A forest growth and yield model describing repeated measurement of plot volume and basal area is presented as an example.

[853:525.1]—051.5

**Keywords:** Growth and Yield

The first control card is a general title card. The second is the job control card. On this card, the first two fields are blank, indicating the program assumes the default values for DELT and SNW. The third field contains the number of plots (22) and the fourth field contains the number of variates (or equations). There are six independent variables; the maximum number of iterations is set at 30; the print option is set to zero to print the results at the last iteration only; the data is located on file 5; there is one format card; no column of 1's is added to the data; there are 11 additional comments cards; and the blank in the last field indicates that the initial estimates are calculated from the data.

Following the job control card are the 11 additional comments cards. Next is the data format card followed by the data itself.

The data are a portion of those collected for a growth and yield study of managed hardwood stands being made by the Northeastern Forest Experiment Station. The program was written in Fortran for an IBM 370/168.

A deck and listing of the computer program described in this publication is available on request with the understanding that the U.S. Department of Agriculture cannot assure its accuracy, completeness, reliability, or suitability for any other purpose than that reported. The recipient may not assert any proprietary rights thereto nor represent it to anyone as other than a Government-produced computer program. For cost information, please write the authors at the: Northeastern Forest Experiment Station, 370 Reed Road, Broomall, Pa. 19008.

## LITERATURE CITED


Clutter, J. L.
1963. **Compatible growth and yield models for loblolly pine.** For. Sci. 9(3): 355-371.

Jennrich, R. I., and P. F. Sampson.
1976. **Newton-Raphson and related algorithms for maximum likelihood variance component estimation.** Technometrics 18(1): 11-17.

Seegrist, D. W., and S. L. Arner.
1978. **Statistical analysis of linear growth and yield models with correlated observations from permanent plots measured at fixed intervals.** *In* Growth models for long term forecasting of timber yields. Publ. FWS-1-78. (Jöran Fries, Harold E. Burkhart, and Timothy A. Max, eds.) Sch. For. Wildl. Res. Va. Polytech. Inst. State Univ., Blacksburg. p. 209-223.

Sullivan, A. D., and J. L. Clutter.
1972. **A simultaneous growth and yield model for loblolly pine.** For. Sci. 18: 76-86.


☆U.S. GOVERNMENT PRINTING OFFICE: 1979—603-011/6

# APPENDIX I

```
*********************************************************************
* CONTROL CARDS
1. TITLE CARD  FORMAT = (10A8)
2. JOB CONTROL CARD
   COLS.  1-10 DELT = END ITERATIONS INDICATOR. WHEN THE
                      PROPORTIONATE CHANGE OF THE LOG LIKELIHOOD
                      FUNCTION IS LESS THAN DELT, ITERATIONS
                      TERMINATE. IF 0 IS READ, DELT IS SET TO 1.E-10
          11-20 SNW  = START NEWTON-RAPHSON PROCEDURE  WHEN THE
                      PROPORTIONATE CHANGE OF THE LOG LIKELIHOOD
                      FUNCTION IS LESS THAN *SNW*,  DEFAULT = .1  .
                      IF THE PROPORTIONATE CHANGE IS GREATER THAN
                      *SNW*, THE FISHER SCORING  PROCEDURE IS USED.
          21-25 N    = NO. OF EXPERIMENTAL UNITS (NO. OF PLOTS).
          26-30 P    = NO. OF REPEATED MEASUREMENTS OR DEPENDENT
                      VARIATES MEASURED ON EACH PLOT.
          31-35 Q    = NO. OF INDEPENDENT VARIABLES
          36-40 NITR = MAX. NO. ITERATIONS. (IF 0, NITR=20).
          41-45 IPR  = PRINT OPTION
                     = 0 PRINT RESULTS AT LAST ITERATION ONLY.
                     = 1 PRINT LOG LIKELIHOOD FUNCTION, DIFFERENCE,
                         AND VALUE OF QUADRATIC FORM EACH ITERATION.
                     = 2 PRINT EVERYTHING BUT NEG. OF INVERSE OF
                         MATRIX OF SECOND DERIVATIVES EACH ITERATION.
          46-50 F    = FILE ON WHICH DATA IS LOCATED (DEFAULT=5).
          51-55 NF   = NO. FORMAT CARDS  (MAX = 3).
          56-60 INT  = INTERCEPT INDICATOR; IF INT NOT EQUAL 0, THE
                      NO. OF INDEPENDENT VARS. IS INCREASED BY 1 AND
                      A COL. OF 1'S IS ADDED TO INDEP. VARS.
          61-65 NC   = NO.OF ADDITIONAL COMMENTS CARDS (CARD TYPE 3)
          66-70 INP  = INPUT INDICATOR.   IF  INP ...
                     = 0 INITIAL ESTIMATES OF BETA AND SIGMA ARE
                         CALCULATED FROM DATA
                     = 1 READ STARTING VALUES OF BETA AND SIGMA
                         (CARD TYPE 6 AND 7) PUNCHED ON PREVIOUS RUN.
3. COMMENTS CARDS - OPTIONAL, READ ONLY IF *NC* ON CARD 2 IS .GT. 0.
          FORMAT = (10A8) - VARIABLE NAMES CAN BE READ HERE; I.E.
          Y1 = LN(VOL)       Y2 = LN(BA)     X1 = 1/AGE   ... ETC.
4. FORMAT OF DATA DESCRIBING THE P*(Q+1) VARIABLES FOR A PLOT.
          (ALL VARIABLES ARE REAL)
5. DATA   (1Y FOLLOWED BY Q X'S; THIS IS REPEATED P TIMES FOR
          THE  P  CORRELATED OBSERVATIONS ON 1 PLOT.  THERE ARE N
          OF THESE OBSERVATIONS)

   READ CARDS 6 AND 7 ONLY IF  INP  ON CARD 2 IS EQUAL TO 1.
6. INITIAL ESTIMATES OF BETA,   FORMAT = (5D16.8)
7. INITIAL ESTIMATES OF SIGMA (UPPER TRIANGULAR PORTION STORED
   COLUMNWISE - I.E. (1,1) (1,2) (2,2) (1,3) (2,3) (3,3) ...
   FORMAT = (5D16.8).

*********************************************************************
```

```
*****************************************************************
*** INSTRUCTIONS FOR CHANGING ARRAY DIMENSIONS. THIS IS REQUIRED ON
    IN MAIN ROUTINE.

    1. DETERMINE P AND Q.
    2. FROM THESE VALUES CALCULATE PP,PPP,QQ,MD1,MD2 USING ARRAY SI
       DEFINITIONS BELOW.
    3. CHANGE DIMENSION SIZE OF ARRAYS TO APPROPRIATE VALUES.
    4. CHANGE MXP TO P, MXQ TO Q, AND MXMD1 TO MD1.
*****************************************************************

*****************************************************************
*** ARRAY SIZE DEFINITIONS
    PP = P*(P+1)/2
    PPP= PP*(PP+1)/2
    QQ = Q*(Q+1)/2
    MD1= Q+PP                    MAX = MXMD1
    MD2= MD1*(MD1+1)/2
*****************************************************************
*** ARRAY DIMENSIONS, MUST BE AT LEAST THE SIZE BELOW.
    REAL*8 DERIV2(MD2),SIGMA(PP),YPY(PP),SIGINV(PP),PLS(PP),
    DERIV1(MD1),PLBB(QQ),PLSS(PPP),DELTA(MD1),Y(P),X(P,Q),
    REAL*8 XPX(PP,Q,Q),XPY(P,Q,P),BETA(Q),PLBS(Q,PP),PLB(Q)
*****************************************************************

*****************************************************************
*** THERE ARE 4 PLACES WHERE FATAL MATRIX INVERSIONS MIGHT OCCUR.
    THESE ARE NUMBERED WITH  MIER. A MESSAGE IS PRINTED WITH THIS
    VALUE TO TELL THE USER THE MATRIX IN WHICH THE INVERSION FAILED
    IF MIER = 1, THE INITIAL X'X COULD NOT BE INVERTED
              2, THE INITIAL ESTIMATE OF SIGMA COULD NOT BE INVERTE
              3, X'S X,THE MATRIX OF 2ND DERIVS. WITH RESPECT TO BE
              4, X'S X, AT LAST ITERATION
*****************************************************************
```

# APPENDIX II

```
SAMPLE PROBLEM,  GROWTH AND YIELD USING CLUTTER'S EQUATIONS
                          22     5     6    30     0     5     1     0    11
*****************************************************************************
 SIMULTANEOUS EQUATIONS                VARIABLE NAMES
Y1 = LN(VOL) AT TIME 1;     Y2 = LN(VOL) AT TIME 2;
Y3 = LN(VOL) AT TIME 3;     Y4 = (LN(BA2) - LN(BA1)*AGE1/AGE2);
Y5 = (LN(BA3) - LN(BA1)*AGE1/AGE3);    X1 = INTERCEPT; X2 = SITE INDEX;
X3 = 1/(PLOT AGE); X4 = LN(BA(T)); X5 = (1-A1/A(T)); X6 = (1-A1/A(T))*SI
***     Y1,Y2,Y3 = F(X1,X2,X3,X4) ;    Y4,Y5 = F(X5,X6)     ***

              Y         X1    X2      X3          X4          X5          X6

*****************************************************************************
(8X,F10.5,2F5.1,4F10.5)
 1 1 1 1    7.61415  1.0 66.0    0.02174    4.26816    0.0         0.0
 1 2 1 2    7.79565  1.0 66.0    0.01923    4.39371    0.0         0.0
 1 3 1 3    7.90747  1.0 66.0    0.01786    4.44811    0.0         0.0
 1 2 2 4    0.61803  0.0  0.0    0.0        0.0        0.11538     7.61539
 1 3 2 5    0.94212  0.0  0.0    0.0        0.0        0.17857    11.78572
 2 1 1 1    6.76869  1.0 60.0    0.02083    3.44829    0.0         0.0
 2 2 1 2    7.06133  1.0 60.0    0.01852    3.67579    0.0         0.0
 2 3 1 3    7.30458  1.0 60.0    0.01724    3.85767    0.0         0.0
 2 2 2 4    0.61065  0.0  0.0    0.0        0.0        0.11111     6.66667
 2 3 2 5    1.00391  0.0  0.0    0.0        0.0        0.17241    10.34483

                                          .

                                          .

                                          .

21 1 1 1    7.16369  1.0 59.0    0.02564    3.96575    0.0         0.0
21 2 1 2    7.39018  1.0 59.0    0.02222    4.13613    0.0         0.0
21 3 1 3    7.58134  1.0 59.0    0.02041    4.27054    0.0         0.0
21 2 2 4    0.69914  0.0  0.0    0.0        0.0        0.13333     7.86667
21 3 2 5    1.11412  0.0  0.0    0.0        0.0        0.20408    12.04082
22 1 1 1    6.64747  1.0 57.0    0.02439    3.44319    0.0         0.0
22 2 1 2    6.92756  1.0 57.0    0.02128    3.65377    0.0         0.0
22 3 1 3    7.13688  1.0 57.0    0.01961    3.79762    0.0         0.0
22 2 2 4    0.65014  0.0  0.0    0.0        0.0        0.12766     7.27660
22 3 2 5    1.02957  0.0  0.0    0.0        0.0        0.19608    11.17647


SAMPLE PROBLEM,  GROWTH AND YIELD USING CLUTTER'S EQUATIONS

PROGRAM CONTROL INFORMATION

NO. PLOTS =                                  22
NO. CORRELATED VARIATES =                     5
NO. INDEPENDENT VARIABLES =                   6
MAX. NO. ITERATIONS =                        30
PRINT OPTION =                                0
INPUT FILE =                                  5
NO. FORMAT CARDS =                            1
INTERCEPT INDICATOR =                         0
DELTA (END ITERATIONS INDICATOR) =   0.100E-05
SNW (NEWTON RAPHSON CUTOFF POINT) = 0.100E+00

ADDITIONAL COMMENTS ABOUT VARIABLES OR OTHER PROBLEM   IDENTIFICATION
*****************************************************************************
*****************************************************************************
 SIMULTANEOUS EQUATIONS                VARIABLE NAMES
Y1 = LN(VOL) AT TIME 1;     Y2 = LN(VOL) AT TIME 2;
Y3 = LN(VOL) AT TIME 3;     Y4 = (LN(BA2) - LN(BA1)*AGE1/AGE2);
Y5 = (LN(BA3) - LN(BA1)*AGE1/AGE3);    X1 = INTERCEPT; X2 = SITE INDEX;
X3 = 1/(PLOT AGE); X4 = LN(BA(T)); X5 = (1-A1/A(T)); X6 = (1-A1/A(T))*SI
***     Y1,Y2,Y3 = F(X1,X2,X3,X4) ;    Y4,Y5 = F(X5,X6)     ***

              Y         X1    X2      X3          X4          X5          X6

*****************************************************************************

DATA FORMAT
************
(8X,F10.5,2F5.1,4F10.5)

Y*Y ADJUSTED FOR MEAN
*********************
  1     0.15031146D+00
  2     0.12919060D+00    0.11208680D+00
  3     0.10987740D+00    0.96057140D-01    0.83542580D-01
  4    -0.52663640D-02   -0.40431550D-02   -0.31945460D-02    0.11842200D-02
  5    -0.13806180D-01   -0.11053770D-01   -0.83516210D-02    0.13327130D-02    0.37339580D-02

THE DETERMINANT OF CROSS PRODUCT MATRIX OF (Y - YBAR)  =      .81933047D-1.

INITIAL ESTIMATES OF REGRESSION COEFFICIENTS  (BETA)
****************************************************
  0.34395569D+01   0.11951271D-01  -0.29515733D+02   0.95348535D+00   0.44052110D+01   0.15154206D-01

INITIAL ESTIMATE OF SIGMA,      NO. OF ADJUSTMENTS =   0
*************************************************************
  1     0.24277870D-03
  2     0.10747270D-03    0.27083830D-03
  3     0.81274030D-04   -0.11589440D-04    0.53396720D-03
  4    -0.21475970D-03    0.21865310D-03   -0.41575310D-03    0.12373000D-02
  5    -0.39769400D-03   -0.36398500D-03    0.14559630D-03    0.62659730D-03    0.23908650D-02

THE DETERMINANT OF SIGMA =      .17336210D-16
*************************************************************
```

```
SIGMA INVERSE
*************
  1     0.7720336D+04
  2    -0.3727836E+04    0.1099525D+05


  3    -0.2553430D+03   -0.2632553D+04    0.3530586D+04
  4     0.1412165D+04   -0.3713461D+04    0.1759382D+04    0.2277022D+04
  5     0.3620952D+03    0.2191034D+04   -0.1122965D+04   -0.1034350D+04    0.1151764D+04

THE VALUE OF THE QUADRATIC FORM =      110.00000
*****************************************************

LOG OF THE LIKELIHOOD FUNCTION =     268.44785
*****************************************************


ITERATION =  21      PROCEDURE USED AT THIS STEP = NEWTON-RAPHSON
*****************************************************************

LOG OF THE LIKLIHOOD FUNCTION =     284.76992          DIFFERENCE =     .2103337D-08      PROPORTIONATE DIFFERENCE =     .7379047E-
*****************************************************************************************************************************

THE VALUE OF THE QUADRATIC FORM =      109.99597
*****************************************************

REGRESSION COEFFICIENTS  (BETA)
*******************************
  0.2975392D+01  0.1114751D-01 -0.1790856D+02  0.1002725D+01  0.4710586D+01  0.9703411D-0

ESTIMATE OF COVARIANCE MATRIX  (SIGMA)
**************************************
  1     0.1047714D-02
  2     0.1433310D-02    0.2003636D-02
  3     0.2552576D-02    0.3568000D-02    0.6577001D-02
  4    -0.5612056E-03   -0.7262475D-03   -0.1367971D-02    0.1171416D-02
  5     0.5212225D-03    0.1402584D-02    0.2+423500-02    0.5410953D-03    0.2995820D-02

DELTA (PARAMETER CHANGE),  NO. OF QUARTERING STEPS =  1      BETA(K), K=1,3 , SIGMA(I,J), (I=1,P;J=I,P)
*****************************************************************************************************************
  0.2488700-06  0.2058290-08 -0.2980120-05 -0.5517460-07  0.7270430-07 -0.6153380-10 -0.5975690-01  0.2600850-01  0.2354430-01
 -0.1467170-01  0.1235800-01 -0.1638100-01 -0.9238070-02  0.3085020-02 -0.4310610-02 -0.6946990-02  0.4672110-02 -0.2345510-02
 -0.2539920-02  0.1237590-02 -0.2493360-03

THE NORM OF THE DIFFERENCE =    0.7603614D-01
*****************************************************

VECTOR OF FIRST DERIVATIVES;  BETA(K), K=1,3 ,  SIGMA(I,J) (I=1,P;J=I,P)
*************************************************************************************************************
 -0.6676450-04 -0.4537160-02  0.1366960-06 -0.3503840-03 -0.7117140-05 -0.4873330-03  0.1394380-07  0.4147170-07  0.8077660-07
 -0.1803120-07  0.3674010-07  0.3076760-07  0.1195780-06 -0.2659000-07  0.5434210-07  0.1159120-06 -0.5137200-07  0.1052220-05
  0.5636460-03 -0.2323980-07  0.2390970-07

THE DETERMINANT OF SIGMA =      .3931329D-17
*****************************************************

INVERSE OF  (-1) * MATRIX OF EXPECTED VALUES OF SECOND DERIVATIVES WITH RESPECT TO BETA
****************************************************************************************
  1     0.1769537D-02
  2    -0.1235232D-04    0.1525796D-06
  3    -0.1414659D-01    0.2786086D-04    0.2690170D-00
  4    -0.1505288D-03    0.3587289D-06    0.1357064D-02    0.2438630D-04
  5    -0.2503[illegible]D-02    0.4525079D-04   -0.1274381D-01   -0.6150126D-04    0.2573507D+00
  6     0.4903240D-04   -0.6773418D-06    0.6638747D-04    0.4292356D-06   -0.3786391D-02    0.5622020D-04

INVERSE OF  (-1) * MATRIX OF EXPECTED VALUES OF SECOND DERIVATIVES WITH RESPECT TO SIGMA(I,J) , (I=1,P;J=I,P)
*************************************************************************************************************
  1     0.9846232D-07
  2     0.1356060D-06    0.1841631D-06


  3     0.2415001D-06    0.3349822D-06    0.6072917D-06
  4    -0.5305595D-07   -0.7091812D-07   -0.1298268D-06    0.6973007D-07
  5     0.8719502D-07    0.1263936D-06    0.2224681D-06    0.2066589D-08    0.1803263D-06
  6     0.1967616D-06    0.2613755D-06    0.4646265D-06   -0.9463069D-07    0.1827579D-06    0.3649596D-06
  7     0.3[illegible]D-06    0.4647876D-06    0.8422205D-06   -0.1733376D-06    0.3219566D-06    0.6490570D-06    0.1176947D-05
  8    -0.7312571D-07   -0.9842686D-07   -0.1800853D-06    0.9484435D-07   -0.5264537D-09   -0.1322850D-06   -0.2422986D-06    0.1306[illegible]
  9     0.1[illegible]D-06    0.1753151D-06    0.3084983D-06    0.4824698D-08    0.2539359D-06    0.2554788D-06    0.4497687D-06    0.297835[illegible]
        0.3622623D-06
 10     0.5[illegible]D-06    0.8274520D-06    0.1526208D-05   -0.3174409D-06    0.5667528D-06    0.1155902D-05    0.2132024D-05   -0.443446[illegible]
        0.7917237D-06    0.3932448D-05
 11    -0.1302253D-06   -0.1752250D-06   -0.3264957D-06    0.1708110D-06    0.4783702D-09   -0.2354230D-06   -0.4388382D-06    0.235023[illegible]
        0.7076692D-08   -0.8179225D-06    0.4352612D-06
 12     0.2138646D-06    0.3121146D-06    0.5588696D-06    0.5474251D-08    0.4499081D-06    0.4546666D-06    0.8151692D-06    0.488300[illegible]
        0.6412768D-06    0.1463030D-05    0.9896355D-08    0.1166753D-05
 13     0.2863206E-07    0.3705225D-07    0.6975221D-07   -0.5576415D-07   -0.2760601D-07    0.4794866D-07    0.9031687D-07   -0.773397[illegible]07
       -0.3572446D-07    0.1701223D-06   -0.1456785D-06   -0.6729116D-07    0.1247468D-06
 14    -0.4702004E-07   -0.6620295D-07   -0.1196098D-06    0.3526986E-07   -0.5375399E-07   -0.9260208D-07   -0.1678384D-06    0.568200[illegible]07
       -0.6439884E-07   -0.3037331D-06    0.9640017D-07   -0.1262114E-06    0.5762250E-07    0.1728243D-06
 15     0.7721706D-07    0.1175139D-06    0.2046294D-06    0.4533504E-07    0.2510013E-06    0.1784401D-06    0.3114182D-06    0.589937[illegible]07
        0.3819896E-06    0.5422791D-06    0.1201403D-06    0.6651670E-06    0.2661673E-07    0.1473658D-06    0.8159030D-06

COVARIANCE MATRIX IN CORRELATION FORM
*************************************
  1     0.1000000E+01
  2     0.9925789E+00    0.1000000E+01
  3     0.9756610E+00    0.9822762D+00    0.1000000D+01
  4    -0.5307778D+00   -0.4740451D+00   -0.4926418D+00    0.1000000E+01
  5     0.5219507D+00    0.5724818D+00    0.5502196D+00    0.2888420D+00    0.1000000E+01
```

Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories and research units are maintained at:

- Beltsville, Maryland.
- Berea, Kentucky, in cooperation with Berea College.
- Burlington, Vermont, in cooperation with the University of Vermont.
- Delaware, Ohio.
- Durham, New Hampshire, in cooperation with the University of New Hampshire.
- Hamden, Connecticut, in cooperation with Yale University.
- Kingston, Pennsylvania.
- Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
- Orono, Maine, in cooperation with the University of Maine, Orono.
- Parsons, West Virginia.
- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- University Park, Pennsylvania.
- Warren, Pennsylvania.

by Thomas A. More

# THE DEMAND FOR NONCONSUMPTIVE WILDLIFE USES:

JUL 9 1979
CLEMSON LIBRARY

## A REVIEW OF THE LITERATURE

CLEMSON UNIVERSITY LIBRARY
JUL 10 1979
SCI., TECH. & AGR. DIV.

FOREST SERVICE GENERAL TECHNICAL REPORT NE-52
1979
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
370 REED ROAD, BROOMALL, PA. 19008

## The Author

THOMAS A. MORE is a research forester with the Northeastern Forest Experiment Station, USDA Forest Service, at Amherst, Massachusetts. He holds B.S. and M.S. degrees from the University of Massachusetts, and a Ph.D. from the University of Michigan. He has made a number of studies on both consumptive and nonconsumptive wildlife users.

MANUSCRIPT RECEIVED FOR PUBLICATION 5 FEBRUARY 1979

## Abstract

Nonconsumptive wildlife use is a generic term for a variety of recreational activities related to wildlife. Primary nonconsumptive uses include general wildlife observation, birdwatching, birdfeeding, and wildlife and bird photography. Secondary activities include nature walks, membership in animal-related organizations, ownership of wildlife pets, and zoo visitation. This report reviews the literature about the demand for nonconsumptive wildlife, based on surveys of the attitudes, preferences, participation, and expenditures for related activities.

# INTRODUCTION

AMERICANS have always been interested in wildlife. From the colonial era throughout the 19th century, wildlife served as an important source of food and clothing. As recently as 1910, the United States was primarily a rural nation with the majority of its population residing on farms or in rural areas (Moeller and More 1976). As the 20th century progressed, however, we witnessed the growth of a modern urban-industrial society where the vast majority of Americans live and work in large cities.

Along with this dramatic shift in place of residence have come major changes in values —many traditional rural values have been supplanted by new urban and suburban lifestyles. Yet, surprisingly, these sweeping changes have had little impact on our interest in wildlife: one recent survey in Oregon found that 95 percent of the adult population participated in some wildlife-oriented activity (Aney and Cowan 1975). Similar surveys in other states might well produce comparable results. But while our interest in wildlife has remained quite high, the expression that we give to this interest (in terms of activity participation) is shifting. Participation in hunting and fishing has not kept pace with the growth of many other activities, and some researchers have even predicted declines in absolute numbers of hunters and fishermen in the not too distant future (Hauser 1962, Chichetti et al. 1969, Hendee and Potter 1976). Conversely, the demand for many nonconsumptive wildlife uses appears to be increasing, both in the population as a whole (Hendee 1969) and as a proportion of the total recreational use that a given area receives (Talbot 1974, Mead and Bookhout 1977). Because such shifts may have important implications for wildlife management agencies, we must examine this demand and some of its underlying factors. In this report I review the literature about the demand for nonconsumptive wildlife use.

Each human use of wildlife can be generally categorized as consumptive or nonconsumptive. Consumptive uses are those that result in or attempt the death of an individual animal (Langenau 1976, Witter 1978). This category encompasses hunting, trapping, fishing, and, in some cases, the collection and use of animals for scientific research.

Nonconsumptive wildlife use, frequently stereotyped as birdwatching, certainly includes birdwatching and general wildlife observation, but also includes wildlife photography, membership in animal-welfare organizations, nature walks and study, and birdfeeding. More marginally, this group of activities might include pet ownership and visits to zoos, circuses, and museums. While such activities are appreciative ues of wildlife and do not result in the death of an animal, they are marginal because they involve observing the animal in other than its natural surroundings.

A variety of typologies of nonconsumptive use have been suggested. For example, Langenau (1975) described four levels of appreciative use: (1) active or passive use of the animal to view, photography, or study; (2) secondary benefit derived from seeing the animal, while engaged in other outdoor recreation; (3) intellectual benefits from reading, thinking, and talking about the animal; and (4) option demand—the value of the animal to nonusers who may wish to use the animal in the future.

Another typology (More 1977) describes the varieties of encounters through which people can experience wildlife: direct-natural, where the animal is encountered in its natural habitat; direct-artificial, where the animal is encountered directly but in an artificial habitat (zoos, circuses, museums, etc.), and vicarious encounters (movies, TV, etc.). These typologies, while conceptually useful, are insufficient for examining the demand for a given activity. Consequently, the remainder of this paper is focused on the specific nonconsumptive activities described above.

Ordinarily demand is expressed in the form of a schedule—the quantity of something purchased at different price levels. This works well for most of the goods and services produced in our society, but some fall outside the market system and are provided by the public sector at only nominal prices. Wildlife and many forms of public outdoor recreation are examples of such "merit" goods. Because such goods are not included in the ordinary market-pricing system, a persistent problem for economists has been to place a value on them so that they can be compared to other resources. In the recreation field, this has led to the development of demand curves based on sophisticated location analysis and willingness-to-pay studies. For nonconsumptive wildlife use, the two major methods of economic valuation are expenditure studies and participation rate studies.

Before turning to the individual studies, however, a word of caution is in order. Social science is less exact than biological science; subtle connotations, definitions, phrasings—all can affect the data reported in a survey. To take these statistics at face value would impute a degree of accuracy that simply does not exist. Prudent readers will recognize these problems and search for similarity of results across several studies, and treat the results of any single report skeptically.

## EXPENDITURE STUDIES

Expenditure studies attempt to determine the economic value of an activity by assessing the amount of money participants spend to engage in it. Several such studies have focused on nonconsumptive wildlife use. The first, a 1966 survey of 35 Calgary Bird Club members (Myers 1968), concluded that the average expenditure for equipment was $199 per member per year. In addition, members spent an average of $168 per person per year on transportation. Both of these figures greatly exceeded hunter expenitures. Furthermore, the average Calgary naturalist was willing to travel much greater distances in pursuit of his hobby than was the comparable Canadian prairie sportsman. Unfortunately, this small sample makes it difficult to generalize the findings to other groups of birders.

In the southeastern United States, 6.1 percent of the households surveyed in 1971 reported expenditures related solely to wildlife enjoyment, wildlife observation, and photography (Horvath 1974a). The average annual expenditure was $197. Based on these figures, an estimated 446,001 southeastern households spent more than $89 million on nonconsumptive activities. These figures do not reflect the expenditures for wildlife enjoyment activities of hunters and fishermen.

Shaw et al. (1978a) questioned avid wildlife observers visiting seven sites in southern Arizona about the replacement value of the equipment they used primarily for nonhunting wildlife appreciation. Most respondents (62 percent) valued their equipment between $100 and $1,500. Seven percent, however, valued it at over $5,000.

A fourth study attempted to assess the economic impact of nonconsumptive wildlife use by estimating total expenditures on an industry-wide basis (DeGraaf and Payne 1975). It concluded that the total direct expenditures attributable to the enjoyment of nongame birds in the United States during

1974 was approximately $500 million, of which $170 million was for birdseed, $15 million for birdhouses and feeders, $3 million for field guides, and $4 million for gift books. Also included were $3.1 million spent on organizational memberships, $115 million for binoculars, and $190 million spent on photographic equipment and processing. The trend in most of these expenditures is upward, perhaps even exceeding the general inflation rate. This could indicate that participation is increasing throughout the population or that expenditures by individual participants are increasing, or both.

Despite the fact that the price of birdseed nearly doubled between 1972 and 1974, the quantity purchased remained nearly constant (Payne and DeGraaf 1975). This suggests that the demand for seed (and the related recreational activity) is relatively inelastic.

By any measure, nonconsumptive wildlife recreation is big business; individuals who enjoy these activities are often prepared to spend large amounts of money pursuing them.

## PARTICIPATION RATE STUDIES

Expenditure studies, while useful in assigning an economic value to an activity, which draws attention to its importance, have been of limited use in helping to understand the underlying dynamics of the activity. To counter this, other studies have focused on participation. Although they vary widely, these studies generally establish participation rates for an activity to examine how the rate is affected by basic factors—typically socioeconomic and demographic variables. When these relationships are known, the demand for the activity can be forecast on the basis of changes in the factors.

Although extensive studies of participation in hunting and fishing have been conducted, far fewer have been attempted for nonconsumptive uses. Studies that have been done were primarily concerned with participation in wildlife observation (including birdwatching and feeding), and wildlife and bird photography. Related activities like nature walking, zoo visitation, pet ownership, and membership in wildlife-related organizations have also received some attention.

### Wildlife observation

As an activity, wildlife observation is a fairly new category for research. Defined as trips made primarily to see or look at wild animals, fish, etc. in natural settings (excluding photographic trips and trips to zoos), it was first included as a specific category in the National Survey of Hunting, Fishing and Associated Wildlife Recreation in 1975. This survey estimated that, in 1975, some 49,314,000 people (about 27 percent of the total U.S. population) participated for a total of 1,589,546,000 visitor days (U.S. Fish and Wildlife Service 1977). Nearly half of these people were also fishermen and/or hunters. The age distribution appears similar to that of the population as a whole, with most participants under age 45 (about 60 percent). Participation declines somewhat in the older age brackets. The income of participants also appears to follow a normal distribution with most participants in the middle to upper middle income classes. Slightly more men (52.6 percent) participated than women (47.4 percent).

A 1971 survey of households in the southeastern United States reports somewhat lower participation than the nation as a whole (Horvath 1974a). In these states, 17.3 percent of the sample population reported participation in wildlife enjoyment activity (including both observation and photography). The population estimates for the southeast as a whole were 1,027,319 households with 471.7 million days of participation. By including questions about the dollar value of these activities to participants, Horvath (1974b) estimated the total value of wildlife activity to exceed $24 billion. The highest use rates were for birds, followed by "animals" and fish.

As in the U.S. Fish and Wildlife Service's national survey, income appeared to be normally distributed. Participation was highest, however, for single females, followed by couples with no children. Generally, increasing numbers of children tended to reduce participation. Little relationship was found between wildlife enjoyment and vacation time or weekends—evidently the activity occurs

throughout the week all during the year. Finally, there was some relationship between participation in wildlife enjoyment activities and occupational status: highest rates were found among retired people (19.2 percent of the total sample) and professional groups (15.2 percent).

In Oregon, 33 percent of the population (505,000 people) were active wildlife viewers (Aney and Cowan 1975). People who viewed wildlife tended to be younger than nonviewers and have incomes either above or below the income level of nonviewers. Other socioeconomic and demographic variables did not differ between the groups (Aney and Cowan 1974).

A 1977 survey of residents of New York State's metropolitan areas found 64 percent of the survey respondents participated in wildlife observation (Brown and Dawson 1978). As a population estimate, however, this may be somewhat high due to nonresponse; the authors note that only 50 percent of the sample population responded to the questionnaire and when nonrespondents were contacted for a subsample they seemed to be somewhat less interested in wildlife than were the respondents. However, sighting birds was a common everyday experience for most (62 percent) of those who did respond, while sighting mammals was common on a weekly basis. Other forms of wildlife (for example, reptiles and amphibians) were not commonly sighted. Interestingly, 44 percent felt there was not enough wildlife in their neighborhoods to give them sufficient observation opportunities, and most people attributed this to the general detrimental effects of city environments on wildlife. As for location, most of the wildlife observation was around the respondents' homes (80 percent), followed by public parks (8 percent).

In Michigan, an estimated 71.2 percent of students in grades 7 through 12 participated in wildlife observation (Pomerantz 1977). In addition, 56 percent had driven and 51 percent had hiked to view wildlife. Driving and hiking to see wildlife was more frequent in rural areas. Participation rates varied little across grades and there were virtually no differences between the sexes. Finally, the esthetic values of wildlife outweighed the utilitarian for these students—77.8 percent said there should be more areas set aside for viewing wildlife. While these figures are impressive, there is some evidence that adult participation in many appreciative uses of wildlife is less tied to childhood experience than are hunting and fishing (Yeosting and Burkhead 1973). Nonetheless, it appears that high school students constitute a major group of nonconsumptive wildlife users.

Wildlife observation consists of more than birdwatching. In Michigan, Langenau (1976) estimated that about 2.6 million people hiked or drove to look for and attempt to see deer. Both participation rates and the actual number of successful sightings were highest in rural areas. About 25 percent of the people who participated in these observation activities had also hunted deer during the preceding year. Most people indicated that they enjoyed seeing deer at any time, but when preferences were given, people preferred seeing moderate numbers of deer in forest habitats during autumn. When compared to nonparticipants, more males were engaged in deer observation, but there were no differences in marital status or number of children. The effects of education and residence are mixed—important in some areas but not in others.

While most wildlife is observed close to home, there are some sites that attract enthusiasts from all over the country. Witter et al. (1978) surveyed visitors to seven such sites in Arizona. Their "typical" respondent was a middle to older aged, well educated, affluent, urban resident. Nearly all (92 percent) respondents were birdwatchers, over 50 percent were wildlife photographers, while 7 percent were hunters. Most (88 percent) belonged or contributed to one or more private organizations that promote nonconsumptive uses.

Overall, the information on wildlife observation is confusing and contradictory. Apparently, participation is casual for the most part, with participants coming from all segments of society. Yet some categories of wildlife observation attract such a devoted following (cf. Witter et al. 1978) that they deserve separate consideration. This is especially true of birdwatching, birdfeeding, and wildlife photography.

### Birdwatching

Birdwatching was first examined as a separate activity by the Bureau of Outdoor Recreation (BOR) in 1965. At that time they estimated that there were 7.1 million birders (5 percent of the total population) in the United States (U.S. Bureau of Outdoor Recreation 1967). In 1970, the National Survey of Fishing and Hunting estimated 6.8 million birdwatchers in the nation (U.S. Bureau of Sport Fisheries and Wildlife 1972), and in 1972, another national survey found 4 percent of the U.S. population participating (U.S. Bureau of Outdoor Recreation 1973).

The most recent national survey (Kellert 1977) disclosed that 22 percent of the population might be considered birdwatchers. However, by examining both interest in and knowledge of birds, three subgroups were defined: committed birders who had both high interest and high knowledge constituted 5 percent of the population; 9 percent had high interest but low knowledge; while an additional 8 percent had high knowledge but little interest. It may be that those who are interested but not knowledgeable participate in activities like birdfeeding; Kellert (1977) speculates that the high knowledge but low interest groups may treat birding as a sort of collecting game focused on the number of species seen. Finally, 78 percent of the people in Kellert's national sample were neither knowledgeable nor interested in birds.

Regional differences in birdwatching participation rates are difficult to assess. Kellert (1977) found no differences between regions, but the 1972 national survey of outdoor recreation (U.S. Bureau of Outdoor Recreation 1973) found participation rates highest in the North Central states. Supporting this, Langenau (1975) reports approximately 35 percent of Michigan residents participated, and in 1974, birdwatching ranked as the 28th most popular activity on southern Michigan game and recreation areas, accounting for 0.3 percent of their total use (Belyea and Lerg 1976). Similarly, in Ohio wildlife areas an estimated 11,147 man-hours of participation represented 0.4 percent of total use (Mead and Bookhout 1977). On the other hand, an even higher rate was reported in Oregon where 48 percent of the population (719,000 people) participated during 1973-1974 (Aney and Cowan 1975). In Idaho, approximately 60 percent of the population was estimated to have participated in birdwatching in 1976 (Fazio and Belli 1977). However, most people participated only occasionally, with the highest participation rates found among purely nonconsumptive users (as opposed to those who participated in both consumptive and nonconsumptive uses).

Evidence of the effects of other socioeconomic and demographic variables is even more equivocal. The 1972 BOR survey described the typical birder as over 25, white, urban, and college educated (U.S. Bureau of Outdoor Recreation 1973). However, Langenau (1975) reported slightly lower levels of participation in highly urban southern Michigan than in the more rural upper peninsula, and Kellert (1977) found no differences between the characteristics of birders and those of the general population, except that people who were knowledgeable tended to be more highly educated regardless of interest. In Saskatchewan, no differences were found between urban and rural residents in their attitudes toward birdwatching (Schweitzer et al. 1973).

As an activity, most birdwatching is done close to home, although many birders do visit other states to pursue their hobby (Horvath 1974a). Seventy-five percent of the activity is on weekends on 1-day outings or outings of shorter duration (U.S. Bureau of Outdoor Recreation 1973). The average duration of an outing is 2.1 hours. For many, birding ranks as their favorite recreational activity (Shaw et al. 1978a).

Based on this information, it appears that birders constitute a small but highly dedicated portion of the population. They appear to come from all walks of life and from every region of the country. In the future, the numbers of dedicated birdwatchers will probably grow slightly, but it is difficult to foresee any major changes in participation.

### Birdfeeding

A second subcategory of wildlife observation is birdfeeding. The market for birdseed (and hence the activity) began to mushroom about 1960 and sales have risen 5 to 10 percent annually since then (Wildlife Management In-

stitute 1975). On a national basis, DeGraaf and Payne (1975) estimated that 20 percent of U.S. households purchased an average of 60 pounds of seed each year, based on data from five major cities (Table 1). Substantial regional variation exists, however. In Massachusetts, the state Audubon Society found that 33 percent of Massachusetts households bought an average of 60 pounds of seed per year, while DeGraaf and Thomas (1974) found 43 percent of the households in Amherst, Massachusetts fed birds. Fifty percent of the residents of New York State metropolitan areas reported feeding wildlife (not limited to birds), mostly around the home; 34 percent had birdfeeders, 16 percent provided water structures for wildlife, 11 percent erected birdhouses, and 10 percent had made plantings to attract wildlife (Brown and Dawson 1978). In the southeast, 17.2 percent of the residents fed birds, while 15.9 percent had birdhouses and 14.2 percent had birdbaths (Horvath 1974a). On the west coast, Aney and Cowan (1975) found that 46 percent (688,000 people) of all Oregonians fed birds, while 245,000 (16 percent) put up birdhouses or nest boxes. Finally, 63 percent of Michigan high school students fed wildlife (not limited to birds) (Pomerantz 1977).

Based on these figures, an estimate of 20 to 25 percent of U.S. households engaged in birdfeeding does not seem unreasonable. Demand appears to be greatest in the Pacific Northwest and North Central regions, and lowest in the southeast (although data from all regions are not available). Demand is apparently inelastic, which indicates that participants are highly committed to this activity or that the value they receive from participation greatly exceeds the cost of seed. Finally, the demand for birdfeeding appears to be increasing slightly, but dramatic rises in participation seem doubtful.

### Bird and wildlife photography

The last subgroup of wildlife observation to require separate treatment is wildlife photography. Certainly the participants are a dedicated group: Henry (1976) reports that wildlife photography is perhaps the major motivation to visit some African national parks and that photographers in pursuit of a particular shot will usually resist any restrictions placed on their activity. Apart from the intensity of their participation, perhaps the principal reason that this group has been singled out for study is because of its economic importance—without doubt the per capita expenditures for this group greatly exceed those of any other nonconsumptive wildlife users.

In 1965, the estimated number of wildlife photographers in the United States was 2.8 million (U.S. Bureau of Outdoor Recreation 1967). By 1970 this had increased to an estimated 4,519,000 people, an increase of 61 percent (U.S. Bureau of Sport Fisheries and Wildlife 1972). In 1972, 2 percent of the U.S. population participated (U.S. Bureau of Outdoor Recreation 1973), while the 1975 National Survey of Hunting, Fishing and Wildlife Associated Recreation (U.S. Fish and Wildlife Service 1977) estimated 7.8 million participants nationally.

On a national level, most participants tend to be white males less than 25 years of age.

**Table 1. Birdseed purchases in five major U.S. cities in 1972.**

| City | Number of households in city | Percentage of households that purchase birdseed | Average amount of seed purchased per household (lb.) |
|---|---|---|---|
| Milwaukee | 442,804 | 19.4 | 64.5 |
| Cleveland | 649,487 | 24.7 | 57.6 |
| St. Louis | 750,164 | 19.8 | 64.5 |
| New York | 3,949,454 | 15.1 | 49.2 |
| Boston | 861,024 | 23.8 | 69.6 |

Source: DeGraaf and Payne 1975.

They are college educated, reside in urban areas, and possess the high income levels required to pursue this expensive hobby. Fifty-six percent of the activity takes place on weekends and has an average duration of 1.6 hours (U.S. Bureau of Outdoor Recreation 1973).

Regionally, the highest participation is found in the West (U.S. Bureau of Outdoor Recreation 1973). In Oregon, for example, 13 percent (184,000 people) of the state's population participated during 1973-1974, and 1 percent (14,000 people) listed photography as their primary viewing activity (Aney and Cowan 1974). In Michigan, however, the rate may be even higher—Langenau (1975) reports approximately 22 percent of the state's population participated in nature photography, with participation somewhat higher in rural areas. In addition, 39 percent of Michigan students reported photographing wildlife during 1976 (Pomerantz 1977). Wildlife was photographed on 1 or more days annually by 18 percent of New York metropolitan residents, although most respondents reported less than 20 days of participation (Brown and Dawson 1978). The sites most often used for photography were around home (33 percent, in urban or suburban parks (21 percent), on private rural property (18 percent), and at rural public parks (15 percent).

In sum, wildlife and bird photography is the least frequent observation activity, but may be the most economically significant. Participation is dominated by white, college educated, urban males. Although it appears to be increasing, the high income required to pursue this expensive hobby may place a ceiling on future growth.

## Secondary wildlife-related activities

A second general category of nonconsumptive wildlife use includes activities where the actual contact with wildlife is but one aspect of an experience, or where the contact is less direct than in those activities previously discussed. This category includes nature walks, zoo visits, ownership of wild or exotic pets, and membership in animal welfare organizations.

*Nature walks.* Nature walks are outings taken primarily to be close to nature. They differ from wildlife observation trips because they are more concerned with natural history as a whole, including plant communities and the nonliving features of an area. Nevertheless, wildlife is an important component of the nature walk.

In 1960, 14 percent of the U.S. population took nature walks (Mueller and Gurin 1962). In 1965, the percentage of the total population participating was the same, but—perhaps due to total population growth—the total number of people patricipating had risen by 8 percent to nearly 20 million (U.S. Bureau of Outdoor Recreation 1967). In addition, the number of occasions had increased by 15 percent. By 1970, total participation had risen to nearly 26 million (U.S. Bureau of Sport Fisheries and Wildlife 1972), while in 1972, 17 percent of the U.S. population participated (U.S. Bureau of Outdoor Recreation 1973).

Most nature walks are taken fairly close to home—approximately 70 percent of the activity is on the weekends with an average duration of 2 hours (U.S. Bureau of Outdoor Recreation 1973). Participation increases slightly as income and educational level increase (ORRR Commission 1962, Mueller and Gurin 1962), with highest participation rates found among college educated people in moderate to high income brackets (U.S. Bureau of Outdoor Recreation 1973). Participation is slightly higher for age groups under 25 (ORRR Commission 1962, U.S. Bureau of Outdoor Recreation 1973), female participants tend to outnumber males (U.S. Bureau of Outdoor Recreation 1973), and whites greatly outnumber blacks (Hauser 1962, U.S. Bureau of Outdoor Recreation 1973). Most participants come from urban areas (U.S. Bureau of Outdoor Recreation 1973) and participation rates are highest in the West, followed by the North Central and Northeast regions (U.S. Bureau of Outdoor Recreation 1973, Mueller and Gurin 1962). Lowest participation rates are found in the South.

Overall, nature walks are a popular activity and there seems to be a rather steady increase in participation, at a rate of approximately 19 percent per year (averaging both total par-

ticipants and total occasions). The BOR estimates that by 1980, 35 million Americans will participate on an average of 7 times per year, and by the year 2000, 53 million people will participate at this rate (U.S. Bureau of Outdoor Recreation 1967). Since nature study constitutes an important use of many forest game and recreation areas (Belyea and Lerg 1976, Tyre and James 1971, Mead and Bookhout 1977), the impact of this activity may be considerable.

*Zoo visits.* Few studies have been conducted to examine zoo visitors despite the fact that "going to the zoo" is one of the most widely shared experiences in modern America. In fact, it is so widely shared that 94 percent of Americans have visited a zoo at least once (Kellert 1977), and to most (77 percent), it is a fascinating and enjoyable experience. On the other hand the commitment to this activity is low —only 16 percent of the people in Kellert's sample indicated frequent zoo visits at some point during their lives. Still, this may make for a surprisingly large industry—in Oregon, an estimated 658,000 people (44 percent of the state's population) visited zoos and wildlife parks in order to view wildlife during 1973-1974 (Aney and Cowan 1974).

Overall, figures taken from the London Zoological Society's attendance estimates indicate that in 1970, 211 zoos in the United States attracted some 109.4 millions visits, an average of 519,000 per zoo (Lucas and Duplaix-Hall 1972). By 1976, this had declined to 88.6 million visits to 183 zoos ($\bar{x}=$ 484.5 thousand), a decrease of 6.6 percent (Olney 1978).

Kellert (1977) further examined zoo enthusiasts—the 16 percent of his sample described above. Demographically, they tended to be young, white females with fathers in professional or skilled occupations. They were raised and currently reside in urban areas of 1 million or more population, and were most heavily concentrated in the mid-Atlantic and East Central states.

Generally, zoo enthusiasts were less interested in and knowledgeable about animals than other groups of appreciative users. They may be motivated more by a general sense of affection for animals (especially pets) than by any special attraction to wild animals. Thus zoos seem to function largely as animal-oriented entertainment centers for residents of large cities.

Zoo visitation may continue to experience a slight decline as the American population ages. However, going to the zoo will remain a popular activity, and individual zoos in large metropolitan areas will continue to attract large numbers of people.

*Pet ownership.* Each year, millions of animals are imported into the United States. While these animals serve a variety of functions ranging from scientific research to culinary specialties, there is little doubt that a great many find their way into the pet trade.

The demand for pets is huge—so large, in fact, that 88 percent of those Kellert (1977) sampled reported owning a pet at some point in their lives, while 72 percent said they had had a pet during the preceeding 5 years. Nearly three-quarters of the respondents said that pets were a major source of satisfaction in their lives. Not surprisingly, companionship was the most frequent reason given for owning a pet, and many owners expressed a strong sense of affection for animals. This affection did not necessarily extend to wildlife as a whole, however.

Socially, pet owners tended to be young, white, and native born, with disproportionate numbers of single, separated, or divorced persons represented. No differences were found either regionally, or between urban and rural residents (Kellert 1977).

With such a high percentage of the population already owning pets, further increases seem unlikely except insofar as they reflect total population growth. However, the type of animal owned may be subject to fads and trends, such as the current interest in snakes. In Kellert's (1977) study, dogs were the most common (cited by over 80 percent of the owners), followed by cats (50 percent), reptiles (25 percent), small rodents (14 percent), fish (10 percent), and horses and ponies (9 percent). In Michigan, 22.5 percent of all students reported keeping wild pets (Pomerantz 1977), while in Oregon, 8 percent of the population kept a native wildlife pet (Aney and Cowan 1974). Thus, pet ownership and trends in the type of animals owned are capable of having major effects on wildlife populations.

More, Thomas A.
1979. **The demand for nonconsumptive wildlife uses: A review of the literature.** Northeast. For. Exp. Stn., Broomall, Pa.
16 p. (U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-52)

Nonconsumptive use is a generic term for a variety of recreational activities related to wildlife including general wildlife observation, birdwatching, birdfeeding, wildlife and bird photography and a number of related other activities. This report reviews the literature about the demand for nonconsumptive wildlife use.

607.2

**Keywords:** Wildlife observation, birdwatching, birdfeeding, wildlife photography, outdoor recreation, wildlife preferences.

More, Thomas A.
1979. **The demand for nonconsumptive wildlife uses: A review of the literature.** Northeast. For. Exp. Stn., Broomall, Pa.
16 p. (U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-52)

Nonconsumptive use is a generic term for a variety of recreational activities related to wildlife including general wildlife observation, birdwatching, birdfeeding, wildlife and bird photography and a number of related other activities. This report reviews the literature about the demand for nonconsumptive wildlife use.

607.2

**Keywords:** Wildlife observation, birdwatching, birdfeeding, wildlife photography, outdoor recreation, wildlife preferences.

More, Thomas A.
1979. **The demand for nonconsumptive wildlife uses: A review of the literature.** Northeast. For. Exp. Stn., Broomall, Pa.
16 p. (U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-52)

Nonconsumptive use is a generic term for a variety of recreational activities related to wildlife including general wildlife observation, birdwatching, birdfeeding, wildlife and bird photography and a number of related other activities. This report reviews the literature about the demand for nonconsumptive wildlife use.

607.2

**Keywords:** Wildlife observation, birdwatching, birdfeeding, wildlife photography, outdoor recreation, wildlife preferences.

More, Thomas A.
1979. **The demand for nonconsumptive wildlife uses: A review of the literature.** Northeast. For. Exp. Stn., Broomall, Pa.
16 p. (U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-52)

Nonconsumptive use is a generic term for a variety of recreational activities related to wildlife including general wildlife observation, birdwatching, birdfeeding, wildlife and bird photography and a number of related other activities. This report reviews the literature about the demand for nonconsumptive wildlife use.

607.2

**Keywords:** Wildlife observation, birdwatching, birdfeeding, wildlife photography, outdoor recreation, wildlife preferences.

*Membership in animal-related organizations.* The interest and concern that many Americans have for animals is reflected in the swelling memberships of various animal-related organizations. These range from small groups with highly specific interests to large, multimillion dollar national and international organizations with a plethora of concerns. In recent years there have been increases in both the numbers of organizations and in the numbers of people who belong to them. One count shows that the number of national animal welfare organizations increased from 9 in 1900 to 128 in 1972 (Witter 1977). Of these 128, 32 were founded from 1951 to 1960, 41 between 1961 and 1970, and 14 in 1971 through 1972. The increase in national animal welfare organizations during the 1960's was the largest of any decade in the 20th century.

Individual memberships also increased at a rapid rate. From 1960 to 1975, membership in the Humane Society rose from 25,000 to 75,000, Defenders of Wildlife from 3,500 to 35,000, and the National Audubon Society from 32,000 to 260,000 (Sheffer 1976).

Despite these large numbers, we know very little about the social characteristics of members. Generally, most conservation organizations draw their members from the upper middle class (Harry et al. 1969, Devall 1970). This was confirmed by the recent survey of *Audubon* subscribers which found that most were employed in professional or technical occupations and had an average household income of over $35,000 per year (National Audubon Society 1977). Male subscribers outnumbered females by 15 percent, and most subscribers were extremely well educated (43 percent had a graduate degree or more). The median age of subscribers was 44, and the majority were married heads of households. They tended to have multiple environmental interests and were active in a variety of civic affairs.

As part of a larger study, Witter (1978) surveyed 200 members of the American Birding Association. In this organization, men outnumbered women by 44 percent, members averaged 17 years of education, the average age was 49, and 37 percent had incomes above $30,000. An impressive 91 percent belonged or contributed to three or more wildlife organizations with a nonconsumptive orientation.

Readers of *National Wildlife* also follow this same pattern: the median age is 47; 27 percent are professionals, with 36 percent living in the suburbs and 26 percent in small towns; two out of three attended college, and 48 percent were graduated; the mean income level is $25,400 (National Wildlife Federation 1977). Birdwatching was the second most popular outdoor activity of these readers, exceeded only by gardening. Politically, members of this group are quite involved, with about one-third having written to their congressman in the preceding year, and as many as 86 percent willing to write if requested.

The highest growth rates in membership in animal-related organizations were between 1950 and 1970, and the rate seems to have declined slightly in recent years. Nevertheless, substantial growth can still be expected through the next decade.

Finally, it should be noted that many people who belong to these organizations also participate in other animal-related activities. The sheer numbers of groups and the divergent interests they represent make it difficult to generalize about the social characteristics of the members.

*Incidental wildlife use.* The final subgroup of wildlife-related activities that deserves attention is "incidental" use. Here, nonconsumptive wildlife use is incidental to a person's primary activity, but may greatly enhance the quality of the recreational experience. Thus hunters or fishermen may enjoy observing birds while pursuing their activity, or backpackers may deviate from their route to examine the tracks of a fox. In some cases, even the feeling that wildlife is near may be important to people—recall Leopold's (1966) description of Old Bigfoot the grizzly, and how the mountain Escudilla seemed to lose its meaning after the bear had been destroyed.

The extent and importance of incidental contacts with wildlife are difficult to determine. Only 8 percent of auto campers in the Superior National Forest cited wildlife as a primary reason for their visit; yet 90 percent of them had seen at least some wildlife during their stay and 96 percent of these people

felt that this had added to their experience (Lime and Cushwa 1969). Similarly, 89 percent of Michigan residents reported that seeing a deer added to the enjoyment of their most frequent recreation (Langenau 1976). The people most affected by sighting a deer were engaged in such activities as small game hunting, deer hunting, camping, and hiking. Birdwatchers, boaters, skiers, and swimmers were less interested.

## STUDIES OF ATTITUDES, PREFERENCES, AND KNOWLEDGE ABOUT WILDLIFE

Underlying, and perhaps even determining, the demand for specific recreational activity are factors such as the attitudes, preferences, and knowledge levels of the participants. To understand the activity, we must understand its participants and nonparticipants at this level as well as at the aggregate demand level. A number of studies have examined these factors and their relationship to nonconsumptive wildlife use.

### Attitude Studies

The vast majority of Americans seem to have a positive attitude toward animals, even if they do not participate in any of the activities discussed here. However, these attitudes may take a variety of forms (cf. Kellert 1976, Pomerantz 1977), or be expressed in a multitude of ways. The attitude most frequently studied has been the antihunting sentiment.

On a national basis, approval of hunting exceeds disapproval. Kellert's (1978) survey, conducted during 1975, found 29 percent of those sampled disapproved of sport hunting, and a national survey conducted in 1976 estimated that 45 percent of the population disapproved of all hunting (Shaw et al. 1978).

Regionally, there are substantial differences in attitudes toward hunting. Kellert (1978) found that hunters were more frequently from the Rocky Mountain and central plains states, antihunters were concentrated in the mid-Atlantic and Pacific Coast states, and nonhunters (those who did not participate and who were not opposed to hunting) were from the Central and Northeast states. Shaw et al. (1978b) reported the greatest disapproval of hunting in the mid-Atlantic and New England states, and the most approval (70 percent) in the South Central states Pacific Coast states were nearly evenly divided. In New Jersey, 38 percent of the population disapproved of hunting during 1972 (Applegate 1973) and this had increased by 5 percent in 1974 (Applegate 1975). During 1975, 32 percent of Michigan residents disapproved (Langenau 1975), while in Iowa, 11 percent disapproved (Dahlgren et al. 1977). In Western states, Gum et al. (1973) found that 16 percent of Arizona residents felt hunting to be cruel, and Aney and Cowan (1974) found that 31 percent of Oregonians expressed disapproval in 1973.

Other factors affect attitudes as well. In virtually all surveys, females have expressed more disapproval of hunting than males (Aney and Cowan 1974, Shaw and Gilbert 1974, Shaw et al. 1978b, Applegate 1973, Pomerantz 1977). Disapproval also increases with urbanization (Applegate 1973, Shaw et al. 1978b), and Kellert (1978) reported that people who are opposed to hunting tend to have been raised in areas of over 1 million population. This may explain why this sentiment is so strong in the Northeast and in mid-Atlantic states.

Another factor of major importance is age. Generally, the greatest amount of antihunting sentiment is found among the young (Shaw et al. 1978b). In fact, Shaw and Gilbert (1974) found 75 percent of U.S. college students were opposed to hunting. Similarly, 75 percent of Michigan students in grades 7 through 12 were opposed to sport hunting, while 25 percent were opposed to all hunting (Pomerantz 1977). Presumably these students, now perhaps several generations removed from rural backgrounds, will continue to oppose hunting throughout their adult life.

Finally, it should be noted that educational level and income appear to have little effect on antihunting sentiment (Aney and Cowan 1974, Shaw et al. 1978b).

What is the future of the antihunting movement, and how will this affect the demand for

the nonconsumptive uses of wildlife? On a national basis, Kellert (1978) foresees modest increases in antihunting sentiment while in New Jersey, Applegate (1975) reported a 5 percent increase over a period of 2 years. On a short-term basis, the age-related findings suggest a moderate growth in antihunting sentiment. Long-term growth rates are somewhat more difficult to predict. It is evident that urbanization has been the underlying cause of the growth in antihunting sentiment, and most sociologists expect that urbanization will continue for some time to come. However, major changes in energy and food supplies could have an ameliorative effect on both antihunting sentiment and urbanization.

The increase in antihunting sentiment frequently has been considered a causal factor in the growing demand for nonconsumptive uses of wildlife (cf. Lime 1976), but its long-term effects are difficult to assess. Certainly the attitude has been partially responsible for the growth in the membership of animal welfare organizations, and this growth can be expected to continue as the current generation of high school and college students join the labor force and are increasingly able to lend financial support to these organizations. Apart from this, the relationship between antihunting sentiments and other nonconsumptive uses is more complex. Most opponents of hunting can be categorized as having either humanistic attitudes (strong affection for individual animals) or moralistic attitudes (concern about exploitation and cruelty) (Kellert 1978). In some instances, participation in an activity may precede the development of antihunting sentiment—thus, pet ownership may lead to the development of humanistic attitudes. In other cases, there is no apparent causal link between these attitudes and participation in the activity. Birdwatching and wildlife and bird photography are specialized activities that require a high level of knowledge and are not dependent upon these attitudes. In fact, most committed birdwatchers, perhaps because they are so knowledgeable, tend to support rather than oppose hunting (Kellert 1977, Witter 1978).

In sum, the antihunting movement will continue to grow over the next few years, but (with the exception of membership in animal-related organizations) this growth will have little effect on the demand for nonconsumptive wildlife activities.

### Knowledge about wildlife

Knowledge of a subject frequently leads to an increasing appreciation of it and hence to an increased demand for associated activities. Much the same process probably applies to wildlife and wildlife-related activities, both consumptive and nonconsumptive. Unfortunately, few studies have investigated people's knowledge about wildlife; those that have, have generally adopted a quiz format where the number of correct responses is used to determine a person's knowledge. With this format, Kellert (1977) found that 20 percent of the respondents in his national sample had a high knowledge of animals, 28 percent scored moderate to high, 28 percent scored moderate to low, and 24 percent had a low level of knowledge.

A variety of factors influence knowledge levels, not the least of which is activity participation. In Kellert's study, committed birdwatchers had by far the highest knowledge level, with naturalistic hunters (those who hunt primarily for the pleasure of being outdoors and near wildlife) a distant second. Surprisingly, antihunters were among the least knowledgeable of all the groups. Other studies have confirmed that hunters tend to be more knowledgeable about wildlife than antihunters (Pomerantz 1977, Dahlgren et al. 1977).

Males tend to be more knowledgeable about wildlife than females, as do people who were raised in rural areas. Both Pomerantz (1977) and Dahlgren et al. (1977) found that knowledge increased with age, but Dahlgren et al. found that knowledge was inversely related to years of education—people with a grade school education outscored others.

Socioeconomic factors may influence people's preferences for different sources of information about wildlife, just as they do participation rates. It remains to be investigated throughout a broad spectrum of the population, but age, educational level, and sex might play major roles in determining such preferences—I can readily imagine that high school students have access to and rely upon different sources than do adults. Indeed, even within a homogenous subpopulation, differences exist.

Among her Michigan 7th to 12th graders, Pomerantz (1977) found that boys were likely to be influenced by a relative, while girls responded more to teachers. This suggests that wildlife information and education may reach substantially different audiences depending upon the communications medium used.

Although we have treated these mediums as sources of information, they also are potential sources of *mis*-information that can have a profound effect on people's perceptions of animals (More 1977). Regrettably, we have no information of the relative accuracy of the different media.

### Wildlife preference studies

Studies based on participation rate and expenditures examine the total demand for a given activity. Yet, even within a given activity there may be substantial variation in demand—are all birds equally attractive to a birder or all the animals at the zoo equally popular? Undoubtedly not! In our rush to estimate total demand, we have largely ignored the species-specific aspects of demand. Of course, such estimates are not easily obtained —the birder may observe a number of different species on a single trip; the zoo visitor dutifully makes the rounds. One approach that has been used to surmount this difficulty has been the wildlife preference survey. Typically, these surveys ask people to rate their preferences for a variety of species, assuming (probably quite correctly) that these preferences are highly correlated with demand.

Few preference surveys have been conducted, and their results seem contradictory. Dagg (1970, 1973) found that the "likability" of birds exceeded that of mammals for the urban residents of Waterloo, Ontario. This may be attributed, in part, to the nuisance value of some of the urban mammals. On the other hand, Bart (1972) found the greatest preference for mammals, specifically horses and dogs. Henry (1976) reported that most visitors to a Kenya National Park devoted by far the greatest amount of their viewing time to two large carnivores—lions and cheetahs; other species in the park attracted little more than a passing glance. In Idaho, nonconsumptive users expressed greatest preference for deer, followed by bear, eagles, elk, bass, and songbirds (Fazio and Belli 1977).

A survey of Massachusetts conservation commissioners (Gray 1975) indicated greatest preferences for mammals (especially deer and moose, beavers, and marine mammals) and birds (particularly raptors, waterfowl, and upland game birds). The least preferred animals included snakes (both poisonous and harmless), porcupines, opossums, salamanders, mudpuppies and newts, bats, mice, moles, and shrews. In New York State, metropolitan area residents preferred to see butterflies, robins, cardinals, sparrows, bluejays, hummingbirds, and squirrels around their homes, while in nearby public parks or the country they preferred woodpeckers, blackbirds and starlings, chipmunks, ducks and and geese, frogs and toads, rabbits, pheasants, and turtles (Brown and Dawson 1978). The least preferred species included pigeons, raccoons, foxes, skunks, and snakes. Finally, in a study confined to birds, Saskatchewan residents who enjoyed bird observation rated songbirds the highest, followed by upland game birds, geese, ducks, other water and shorebirds, and birds of prey (Schweitzer et al. 1973). It is worth noting that, while these were ranked in descending order, preference ratings for all were highly positive.

There are many factors that may affect preferences. Socioeconomic and demographic influences undoubtedly exist but have yet to be studied. Participation in a recreational activity group is an important influence; consumptive users, for instance, may rank species differently from nonconsumptive users (cf. Fazio and Belli 1977). The level of knowledge about wildlife may also modify preferences, and relative scarcity certainly plays a most important role —the sighting of a Ross' gull, a very rare bird, attracted more than 1 thousand people per day from all over the United States.[1] Preferences also may vary with viewing situations—it can be one thing to enjoy watching a squirrel in a park, but quite another to discover it in your birdfeeder. Finally, physical characteristics of

[1]*Boston Globe*. 9 March, 1975, p. 1.

an animal—form, size, color, voice, etc. may have a major effect on preferences.

We have very limited knowledge of wildlife preferences. This important and neglected research topic should receive more attention in the future.

## SUMMARY AND CONCLUSION

Research in outdoor recreation is relatively new though some activities—like hunting, fishing, and wilderness use—have received a reasonable amount of research attention. Where this is the case, research has progressed in a series of stages, with a different type of question being asked at each stage. Hunting provides an example. Here, we began with studies like the National Surveys of Hunting and Fishing, which attempted to estimate total participation and the expenditures of participants. The basic question asked was How much?—both in terms of participation and economic impact. This was a logical starting point, and such studies often dramatize the importance of an activity.

During the 1960's the emphasis began to shift, and increasing numbers of studies examined the socioeconomic and demographic characteristics of hunters—the question became Who hunts? In the 1970's, the question has again shifted, this time to ask more subtle and difficult questions about *why* people hunt; there have been increasing numbers of studies on hunter attitudes, behavior, satisfactions, and motives. These categories are greatly oversimplified and often overlap, yet they do provide an interesting perspective from which to assess the current state of our knowledge about nonconsumptive wildlife activities.

On this basis, I believe that studies of nonconsumptive uses are currently in a transitional phase. Many of the studies discussed here are concerned primarily with establishing total participation rates for an activity, and this concern will probably continue to be important. However, the number of studies concerned with the characteristics of participants has been increasing rapidly in the past several years and can be expected to be the dominant type of study in the immediate future. With a few exceptions (cf. Kellert 1977), studies of the underlying motives for these activities have been relatively rare. However, these, too, will increase in frequency as we begin to develop our knowledge of participants' characteristics.

Under the circumstances, a certain amount of confusion is inevitable. Different surveys use different definitions and activity categories; or perhaps ask the same questions in different ways, which produces different results. For example, one survey might define birdwatching as trips taken to observe birds, while another survey might include all the casual observations a person makes around home—a situation bound to lead to different estimates of the number of birders. Langenau (1976) suggested that the lack of standardized categories and definitions is a major factor impeding progress in this field, and I believe he is well justified. Standardization takes time and effort, and doubtless we will improve as we go along. In the meantime, readers should accept the figures in this report with appropriate caution—they are not invalid in and of themselves, but comparisons made between surveys must be considered provisional.

Despite the disparities among surveys, it is evident that a large number of Americans (including those who also hunt and fish) enjoy nonconsumptive uses of wildlife. Based upon the series of recent surveys examined here, approximately 27 percent of the U.S. population participates in wildlife observation, 5 percent enjoy birdwatching, 2 percent are wildlife photographers, and 20 to 30 percent of U.S. households feed birds. Most of these activities appeal to people from all walks of life—there are few socioeconomic or demographic differences between participants and the general population. Overall, participation appears to be highest in the West, the north-central and northeastern regions, and lowest in the South.

Recently a panel of "experts" predicted that by the year 2000, nonconsumptive use would be the dominant form of wildlife-related recreation (Shafer and Moeller 1974). Depending on their point of view, others have hailed or decried the decline of hunting and growth of nonconsumptive uses, but always with a sense of inevitability. However, this sense that we are undergoing or about to undergo dramatic changes in activity participation rates may

not be correct. Certainly if one added together all the participation in each of the nonconsumptive uses discussed here, it would probably greatly exceed the total consumptive uses today. In 1975, the number of wildlife observers alone exceeded the number of hunters (U.S. Fish and Wildlife Service 1977). But growth is another matter. For wildlife observation there is too little data to project any trend. Birdwatching, however, seems to be increasing slightly, but may not even be keeping pace with total population growth. Wildlife photography is increasing rapidly, but the number of participants is still so small that such changes may pass unnoticed. In addition, the high cost of this activity may establish a ceiling on the number of participants.

Zoo visits and pet ownership are both extremely common in the United States today. In fact they are so common that the growth potential is very limited. However, the ownership of wildlife pets is subject to fads, and we would do well to monitor it.

Other activities associated with wildlife appreciation do appear to be increasing. Nature walks (already popular with 17 percent of the population) and membership in animal-related organizations will continue to grow moderately during the next few years, as will the amount of antihunting sentiment. However, it is unclear how increases in these activities will influence the demand for other nonconsumptive uses, so their total impact on wildlife populations may be small.

If this is the case, where is the growth we've heard so much about in recent years? The answer is simple—it's in our increasing recognition of a phenomenon that has been an actuality for a long time: the tremendous public interest in wildlife and the variety of expressions it has. Only now are we beginning to appreciate the scope of the interest.

## ACKNOWLEDGMENTS

I am indebted to Dr. Dennis Schweitzer, USDA Forest Service Resources Planning Act Assessment Staff, for his support of this review. I am also most grateful to Drs. Stephen Kellert, Dale Potter, William Shaw, and Daniel Witter for their excellent criticism of an earlier draft.

## LITERATURE CITED

Aney, W. W., and C. D. Cowan.
1974. **Oregon wildlife preferences and activity survey, summary report.** Oreg. Wildl. Comm., Corvallis, 23 p.

Aney, W. W., and C. D. Cowan.
1975. **Survey shows wildlife important recreational resource.** Oreg. Wildl. 30(2):8-9.

Applegate, J.
1973. **Some factors associated with attitudes toward deer hunting in New Jersey residents.** *In* J. C. Hendee and C. Schoenfeld, eds. Human dimensions in wildlife programs. Wildl. Manage. Inst., Washington, D. C. p. 111-117.

Applegate, J.
1975. **Attitudes toward deer hunting in New Jersey: A second look.** Wildl. Soc. Bull. 3(1): 3-6.

Bart, W. M.
1972. **A hierarchy among attitudes toward animals.** J. Environ. Educ. 3(4):4-6.

Belyea, G. Y., and J. M. Lerg.
1976. **Public use of southern Michigan game and recreation areas.** Mich. Dep. Nat. Resour. Wildl. Div. Rep. 2754. 96 p.

Brown, T. L., and C. P. Dawson.
1978. **Interests, needs and attitudes of New York's metropolitan public in relation to wildlife.** Cornell Univ. Nat. Resour. Ext. Ser. 13. 53 p.

Chicchetti, C. J., J. J. Seneca, and P. Davidson.
1969. **The demand and supply of outdoor recreation, an economic analysis.** Rutgers Univ. Bur. Res., New Brunswick, N. J. 301 p.

Dagg, A. I.
1970. **Wildlife in an urban area.** Nat. Can. (Que.) 97:201-212.

Dagg, A. I.
1973. **Reactions of people to urban wildlife.** *In* Willdlife in an urbanizing environment. Holdsworth Nat. Resour. Cent., Plann. and Resour. Dev. Ser. 28. Amherst, Mass. p. 163-165.

Dahlgren, R., A. Wywialowski, T. Bubolz, and V. Wright.
1977. **Influence of knowledge of wildlife management principles on behavior and attitudes toward resource issues.** Trans. North Am. Wildl. and Nat. Resour. Conf. 42:146-155.

DeGraaf, R., and B. Payne.
1975. **Economic values of nongame birds and some urban wildlife research needs.** Trans. North Am. Wildl. and Nat. Resour. Conf. 40: 281-287.

DeGraaf, R. and J. Thomas.
1974. **A strategy for wildlife research in urban areas.** *In* Wildlife in an urbanizing envronment. Holdsworth Nat. Resour. Cent., Planning and Resour. Dev. Ser. 28. Amherst, Mass. p. 53-56.

Devall, W. B.
1970. **Conservation: An upper-middle class**

**social movement.** A replication. J. Leisure Res. 2(2):123-126.

Fazio, J. R., and L. A. Belli.
1977. **Characteristics of nonconsumptive wildlife users in Idaho.** Trans. North Am. Wildl. and Nat. Resour. Conf. 42:117-128.

Gray, G.
1975. **Nonconsumptive demand for wildlife by municipal conservation commissioners in Massachusetts.** M.S. thesis. Univ. Mass., Amherst.

Gum, R., W. Martin, A. Smith, and C. Depping.
1973. **Participation and expenditures for hunting, fishing, and general rural outdoor recreation in Arizona.** Univ. Ariz. Agric. Exp. Stn. Res. Rep. 270. 27 p.

Harry, F., R. Gale, and J. Hendee.
1969. **Conservation: An upper-middle class social movement.** J. Leisure Res. 1(3):246-254.

Hauser, P. M.
1962. **Demographic and ecological changes as factors in outdoor recreation.** *In* T. J. MacQueen, ed. Trends in American living and outdoor recreation. Outdoor Rec. Res. Rev. Comm. Stud. Rep. 22. p. 27-59.

Hendee, J. C.
1969. **Appreciative versus consumptive uses of wildlife refuges: Studies of who gets what and trends in use.** Trans. North Am. Wildl. Nat. Resour. Conf. 34:252-264.

Hendee, J. C., and D. R. Potter.
1976. **Hunters and hunting: Management implications of research.** *In*: Proceedings of the Southern States Recreation Research Applications Workshop. USDA For. Serv. Gen. Tech. Rep. SE-9. p. 137-161.

Henry, W.
1976. **A preliminary report on visitor use in Ambroseli National Park.** Inst. Dev. Stud. Work. Pap. 263. Univ. Nairobi, P.O. Box 30197, Kenya. 37 p.

Horvath, J.
1974a. **Detailed analysis, economic survey of wildlife recreation.** Environ. Res. Group, Ga. State Univ., Atlanta. 68 p. illus.

Horvath, J.
1974b. **Economic survey of southeastern wildlife and wildlife oriented recreation.** Trans. North Am. Wildl. and Nat. Resour. Conf. 39: 187-194.

Kellert, S.
1976. **Perceptions of animals in American society.** Trans. North Sm. Wildl. and Nat. Resour. Conf. 41:533-546.

Kellert, S.
1977. **The attitudes and characteristics of various animal activity groups other than hunters.** Rep. to the USDI Fish and Wildl. Serv. 49 p.

Kellert, S.
1978. **Characteristics of hunters and antihunters.** Trans. North Am. Wildl. and Nat. Resour. Conf. 43:412-423.

Langenau, E.
1975. **Appreciative uses of Michigan white-tailed deer: Progress report.** Mich. Dep. Nat. Resour. Lansing. 19 p.

Langenau, E.
1976. **Nonconsumptive uses of the Michigan deer herd. Ph.D. dissertation.** Mich. State Univ., East Lansing. 94 p.

Leopold, A.
1966. **A Sand County almanac and sketches here and there.** Oxford Univ. Press, London. 226 p.

Lime, D. W.
1976. **Wildlife is for nonhunters, too.** J. For. 74(9):600-604.

Lime, D. W., and C. T. Chushwa.
1969. **Wildlife esthetics and auto campers in the Superior National Forest.** North Cent. For. Exp. Stn., St. Paul, Minn. 8 p. USDA For. Serv. Res. Pap. NC-32.

Lucas, J., and N. Deuplaix-Hall.
1972. **International zoo yearbook, vol. 12.** Zool. Soc., London. 416 p.

Mead, E. R., and T. A. Bookhout.
1977. **An analysis of public use of state wildlife areas in Ohio.** Final Rep. Ohio Dep. Nat. Resour., Div. Wildl., Columbus. 126 p.

Moeller, G., and T. More.
1976. **Future urban recreation demands on U.S. National Parks and Forests.** *In* J. Andersen, ed. Trees and forests for human settlements. Univ. Toronto Press. 417 p.

More, T.
1977. **An analysis of wildlife children's stories.** *In* Children, nature and the urban environment: A symposium fair. USDA For. Serv. Gen. Tech. Rep. 61-30. p. 84-92.

Mueller, E., and G. Gurin.
1962. **Participation in outdoor recreation: Factors affecting demand among American adults.** Outdoor Rec. Resour. Rev. Comm. Stud. Rep. 20. U.S. Gov. Print. Off., Washington, D. C. 94 p.

Myres, M. T.
1968. **A sample survey of the expenditures of naturalists.** Can. Audubon 30:12-20.

National Audubon Society.
1977. **The Audubon subscriber.** Starch INRA Hooper, Mamaroneck, N. Y. 121 p.

National Wildlife Federation.
1977. **Meet the people who read National Wildlife.** Nat. Wildl. 15(6):38-39.

Olney, P. J. S.
1978. **International zoo yearbook, vol. 18.** Zool. Soc. London. 462 p.

Outdoor Recreation Resources Review Commission.
1962. **Study report 26.** U.S. Gov. Print. Off., Washington, D.C. 72 p.

Payne, B., and R. M. DeGraaf.
1975. **Economic value associated with human**

**enjoyment of nongame birds.** Proc., Symposium on management of forest and range habitats for nongame birds. USDA For. Serv. Gen. Tech. Rep. WO-1, p. 6-10.

Pomerantz, G.
1977. **Young people's attitudes toward wildlife.** Wildl. Div. Rep. 2781. Mich. Dep. Nat. Resour., Lansing. 79 p.

Schweitzer, D. H., D. A. Scott, A. W. Blue, and J. P. Secter.
1973. **Recreational preferences for birds in Saskatchewan.** *In* J. C. Hendee and C. Schoenfeld, eds. Human dimensions in wildlife programs. Wildl. Manage. Inst., Washington, D.C. p. 42-49.

Shafer, E. L., and G. Moeller.
1974. **Wildlife priorities and benefits: Now, 2000, and beyond.** Trans. North Am. Wildl. and Nat. Resour. Conf. 39:208-220.

Shaw, D., and D. Gilbert.
1974. **Attitudes of college students toward hunting.** Trans. North Am. Wildl. and Nat. Resour. Conf. 39:157-162.

Shaw, W., D. Witter, D. King, and M. Richards.
1978a. **Nonhunting wildlife enthusiasts and wildlife management.** Paper presented at West. Assoc. Fish and Wildlife Agencies and Wes. Div.—Am. Fisheries Soc. Annu. Meet. July 17-20, 1978. San Diego, Calif. 10 p. Typewritten.

Shaw, W., L. Arthur, E. Carpenter, R. Gum, and D. Witter.
1978b. **The American disposition toward hunting in 1976.** Wildl. Soc. Bull. 6(1)33-35.

Sheffer, V.
1976. **The future of wildlife management.** Wildl. Soc. Bull. 4(2):51-54.

Talbot, L.
1974. **Nongame wildlife: A federal perspective.** Trans. North Amer. Wildl. and Nat. Resour. Conf. 39:81-86.

Tyre, G., and G. James.
1971. **Length and rate of individual participation in various activities on recreation sites and areas.** USDA For. Serv. Res. Note SE-161.

U.S. Bureau of Outdoor Recreation.
1967. **The 1965 survey of outdoor recreation activities.** U.S. Dep. Inter., Bur. Outdoor Rec. 202 p. typewritten.

U.S. Bureau of Outdoor Recreation.
1973. **Outdoor recreation: A legacy for America.** Summary of Appendix "A", an economic analysis. U.S. Dep. Inter., Bur. Outdoor Rec. 60 p.

U.S. Bureau of Sport Fisheries and Wildlife.
1972. **National survey of fishing and hunting.** U.S. Dep. Inter. Bur. Sport Fish. and Wildl. Resour. Publ. 95. 108 p.

U.S. Fish and Wildlife Service.
1977. **1975 National survey of hunting, fishing, and wildlife associated recreaton.** U.S. Dep. Inter., Fish and Wildl. Serv. 100 p.

Wildlife Management Institute.
1975. **Current investments, projected needs and potential new sources of income for nongame fish and wildlife programs in the United States.** Wildl. Manage. Inst., Washington, D.C. 77 p.

Witter, D. J.
1977. **Attitudes toward animals and their uses: Literature citations and animal welfare organization data.** Work. Pap. 16. U.S. Dep. Agric., Econ. Res. Serv. 79 p.

Witter, D. J.
1978. **Birdwatchers', hunters', and wildlife professionals' beliefs about the importance and management of wildlife.** Ph.D. dissertation. Sch. Renewable Nat. Resour., Univ. Ariz., Tucson. 188 p.

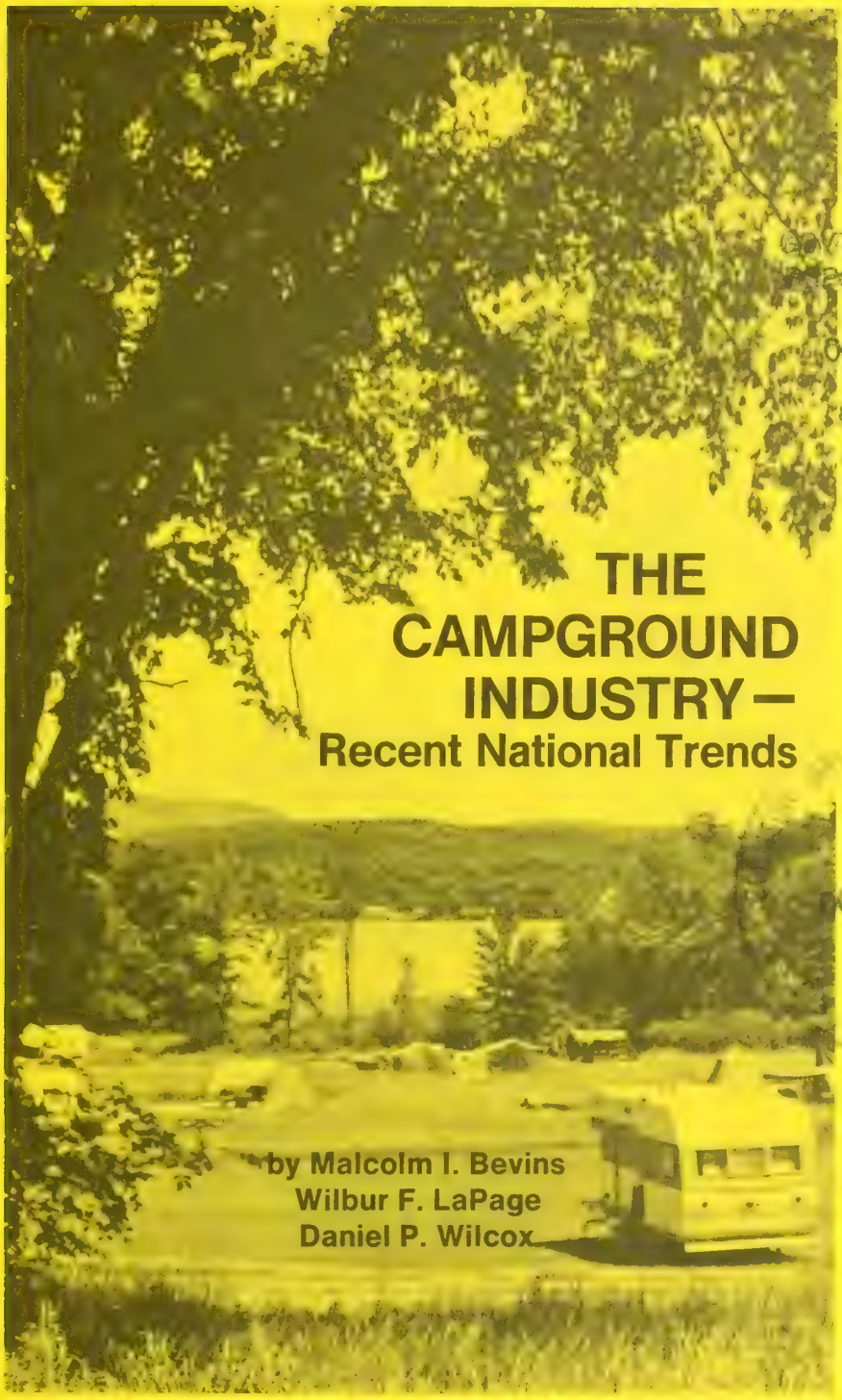
Witter, D. J., W. W. Shaw, D. A. King, and M. T. Richards.
1978. **Nonconsumptive wildlife enthusiasts visiting southern Arizona: Their beliefs about wildlife management programs and policies.** Trans. 1978. Ariz.-N. Mex. Chap. Wildl. Soc.: p. 93-113.

Yeosting, D. R., and D. L. Burkhead.
1973. **Significance of childhood leisure behavior: An exploratory analysis.** J. Leisure Res. 5(1):25:36.

☆U.S. GOVERNMENT PRINTING OFFICE: 1979—603-011/21

Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories and research units are maintained at:

- Amherst, Massachusetts.
- Beltsville, Maryland.
- Berea, Kentucky, in cooperation with Berea College.
- Burlington, Vermont, in cooperation with the University of Vermont.
- Delaware, Ohio.
- Durham, New Hampshire, in cooperation with the University of New Hampshire.
- Hamden, Connecticut, in cooperation with Yale University.
- Kingston, Pennsylvania.
- Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
- Orono, Maine, in cooperation with the University of Maine, Orono.
- Parsons, West Virginia.
- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- University Park, Pennsylvania.
- Warren, Pennsylvania.



GOVT. DOCUMENTS
REPOSITORY ITEM
OCT 3 1979
CLEMSON
LIBRARY

# THE CAMPGROUND INDUSTRY — Recent National Trends

OCT 4 1979
TECH. & REF. DIV.

by Malcolm I. Bevins
Wilbur F. LaPage
Daniel P. Wilcox

**FOREST SERVICE GENERAL TECHNICAL REPORT NE-53**
**1979**

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
370 REED ROAD, BROOMALL, PA. 19008

THIS REPORT contains an assessment of the national supply and demand situation for developed camping. Preparation of this document was funded in part by the Forest Service, U.S. Department of Agriculture, and constitutes a contribution toward meeting the resource assessment requirements of the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA).

This study was sponsored by:

1) The Northeastern Forest Experiment Station, Forest Service, U.S. Department of Agriculture (Agreement No. 23-858)
2) The Vermont Agricultural Experiment Station, University of Vermont.

This report represents a research contribution to the Northeastern States Cooperative Regional Research Project NE-100 "Recreation Marketing Adjustments in the Northeast," and the Vermont Agricultural Experiment Station Project S-202 "Supply/Demand Assessment for Camping-Picnicking."

This is Report No. MP-104 of the Agricultural Experiment Station of the University of Vermont, Burlington, Vermont, an Equal Opportunity Employer.

## The Authors

MALCOLM I. BEVINS is an Associate Resource Economist at the University of Vermont Agricultural Experiment Station and serves as chairman of the 13-state NE-100 Technical Research Committee, analyzing recreation and tourism trends and their impact in the Northeast.

WILBUR F. LaPAGE is the leader of a research project developing national social indicators of outdoor recreation trends for the U.S. Forest Service at the Northeastern Forest Experiment Station's research laboratory in Durham, New Hampshire.

DANIEL P. WILCOX received a B.S. degree in recreation resource management from the University of Vermont in 1976. He is a Research Assistant at the University of Vermont Agricultural Experiment Station.

MANUSCRIPT RECEIVED FOR PUBLICATION 16 FEBRUARY 1979

## INTRODUCTION

THIS REPORT evaluates the national supply and demand situation for the campground industry. A basic assessment was made in 1975 by the U.S. Forest Service (1976) to fulfill the requirements of the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA).

To update the information reported in the "Developed camping and related activities" section of the first RPA assessment, a search was undertaken for the most current data. Published and unpublished materials were obtained from public agencies, private industry, and universities. Public agencies contributing recreation resource statistics to this report include the U.S. Forest Service, the U.S. National Park Service, and the U.S. Army Corps of Engineers. A substantial portion of the supply situation analysis for developed camping is based on data compiled by two major campground directory publishers (Rand McNally and Woodall).

Several recent university- and government-sponsored research studies are cited. These include the study financed by the Heritage Conservation and Recreation Service (formerly U.S. Bureau of Outdoor Recreation [BOR]), entitled "Public willingness to pay for camping and picnicking," and the NE-100 Regional Research Project, which analyzes emerging trends in recreation. Included also is a specially conducted opinion survey of 12 hand-picked public and private camping industry leaders, in which each was asked to predict what camping may be like in 1985.

## DEMAND SITUATION FOR DEVELOPED CAMPING

### The camping public

*Camping market surveys.* Statistics from a series of national surveys indicate trends in camping market growth since 1960 (Table 1). Although variations in survey methodologies do not permit exact comparisons among all survey findings, the historical data presented in Table 1 suggest that the number of campers

**Table 1.—Number of campers in the U.S., 1960–1977**

| Date of survey | Persons | | Households | | Source |
|---|---|---|---|---|---|
| | Number (millions) | Percent of population | Number (millions) | Percent of population | |
| 1960 | 10 | 8 | — | — | Ferris et al. 1962 |
| 1960 | — | — | 4 | 8 | U.S. Forest Service 1976:65 |
| 1965 | — | — | 6 | 10 | U.S. Forest Service 1976:65 |
| 1965 | 18 | 10 | — | — | LaPage 1973:1 |
| 1971 | 39 | 19 | 13 | 19 | LaPage 1973:3 |
| 1972 | 23 | 11 | — | — | U.S. Bureau of Outdoor Recreation 1973:23 |
| 1973 | 43 | 20 | 14 | 21 | Kottke et al. 1975:3 |
| 1973 | 54 | 26 | 20 | 30 | A. C. Nielson Co. 1976 |
| 1976 | — | — | 23 | 32 | Kampgrounds of America 1976 |
| 1976 | 58 | 27 | 22 | 30 | A. C. Nielson Co. 1976 |
| 1976-77 | 52 | 30 | — | — | [a] |

[a]Heritage Conservation and Recreation Service, U.S. Dep. Inter. 1978. Preliminary unpublished findings of the 1977 Outdoor Recreation Survey. Table 16.

and camping households has at least tripled since 1960.

Comparative findings from two national camping surveys (LaPage 1971, Kottke et al. 1973) indicate that the number of camping households increased from 12.6 million in 1971 to 14.3 million in 1973, an increment of 13 percent. Statistics from a 1976 A. C. Nielsen survey reveal that nationally there were 21.8 million camping households in 1976, an 8 percent increase over the number estimated by Nielsen in a similar survey conducted in 1973. For the 1976 survey, sports participation survey data were collected through telephone interviews with a random sample of U.S. households. Responses were obtained from 3,000 households. The results of studies done by LaPage (1971), Kottke et al. (1973), and Nielsen (1973, 1976) indicate that while the number of campers is increasing, the *rate of growth* in the United States camping market may be declining. If true, this evidence of slower market growth corroborates the conclusion of the initial RPA report that "demand for camping might be approaching a temporary saturation point" (U.S. Forest Service 1976:67).

A study conducted for the NE-100 Technical Research Committee in October 1977 examined patterns of participation by age group in many different activities in the Northeastern States (Table 2). Camping was dis-

**Table 2.—Percentage of adult population, by age group and total, that participates in outdoor activities. Northeastern states, 1977**

| Activity | Age group | | | | All ages[a] |
|---|---|---|---|---|---|
| | 18-34 | 35-49 | 50-64 | 65+ | |
| Bicycling | 64.9 | 46.0 | 24.8 | 7.4 | 41.7 |
| Boating | | | | | |
| Sail | 17.4 | 11.6 | 6.5 | 2.7 | 11.0 |
| Motor | 30.0 | 21.5 | 15.2 | 5.4 | 20.5 |
| Camping | | | | | |
| Backpack | 17.6 | 5.2 | 3.0 | 0.9 | 8.3 |
| Tent | 29.5 | 14.5 | 6.5 | 2.2 | 15.9 |
| Recreation vehicle | 14.5 | 13.0 | 8.7 | 2.7 | 10.9 |
| Canoeing | 21.0 | 11.7 | 5.8 | 1.1 | 11.9 |
| Fishing | | | | | |
| Freshwater | 32.9 | 24.5 | 18.7 | 9.4 | 23.7 |
| Saltwater | 24.0 | 21.8 | 16.7 | 6.1 | 19.0 |
| Golfing | 18.7 | 17.8 | 13.7 | 8.3 | 15.7 |
| Hiking | 36.2 | 27.0 | 18.3 | 9.4 | 25.4 |
| Hunting | 15.1 | 11.6 | 8.3 | 4.7 | 11.0 |
| Ice skating | 36.7 | 24.3 | 10.7 | 1.6 | 21.8 |
| Jogging | 47.4 | 26.3 | 12.2 | 3.6 | 26.8 |
| Motorcycling | 23.3 | 8.7 | 1.8 | 0.4 | 10.9 |
| Picnicking | 70.6 | 68.9 | 55.5 | 29.8 | 60.3 |
| Skiing | | | | | |
| Downhill | 20.2 | 9.5 | 4.1 | 0.2 | 10.5 |
| Cross-country | 5.6 | 5.0 | 2.8 | 0.2 | 4.0 |
| Water | 18.9 | 8.7 | 3.5 | 0.7 | 9.8 |
| Snowmobiling | 13.6 | 9.0 | 3.9 | 0.9 | 8.2 |
| Swimming | 80.4 | 68.7 | 44.8 | 15.2 | 58.9 |
| Tennis | 53.6 | 31.6 | 12.6 | 2.0 | 30.2 |
| Other | 8.4 | 5.5 | 2.2 | 0.9 | 5.0 |
| (Percent in adult population) | (34.6) | (26.7) | (23.3) | (15.4) | (100.0) |

[a]Weighted by percent of Northeast population in each age group, according to 1970 Census of Population.

Source: NE-100 Technical Research Committee, Northeastern States Agricultural and Forestry Experiment Stations. Unpublished data, December, 1977.

aggregated into backpacking, tent camping, and recreational vehicle (RV) camping. The weighted participation rates for each group were approximately 8 percent, 16 percent, and 11 percent, respectively. Compared with other outdoor recreation, camping stands out as an important activity.

*Visits to National Parks and Forests.* Federal camping area use statistics also are useful indicators of camping activity. The U.S. Forest Service estimates that visitor days of camping totaled approximately 37.5 million during 1977 at developed Forest Service campgrounds (Table 3). Except for the 5.7 percent increase in visitor days recorded between 1974 and 1975, camping at developed Forest Service campgrounds appears to be relatively stable or declining slightly.

The National Park Service (NPS) is another source of Federal campground activity level data. Over the 6-year period 1972–1977, overnight stays at NPS campgrounds increased in each year except 1974 (Table 4). Recent monthly NPS statistics indicate that the number of persons camping in National Parks decreased during Summer 1978 and increased during Fall 1978 (Table 5). Total National Park visits increased in all but two months from January through October 1978.

The following statement, which appeared in the 1975 annual public use report of the U.S. National Park Service (1976), suggests that NPS campgrounds may be inadequate to meet an increasing camping demand:

> Capacity constraints and possible further reductions in the number of sites significantly affect the capability of NPS operated campgrounds to fulfill total demand for camping by park visitors.

NPS officials hope that implementation of a campsite reservation system for heavily used parks and increased reliance on private campgrounds (including those operated by concessionaires) will help satisfy a growing demand for NPS camping.

*Camper characteristics.* Annual household incomes of campers are higher than the nationwide average, according to a 1976 Kampgrounds of America (KOA) camping survey (Table 6). KOA mailed 5,000 questionnaires to a sample of U.S. families. Eighty percent of the questionnaires were returned. Of the camping households surveyed, 44 percent reported incomes in excess of $15,000 annually, as compared with the U.S. average of 37 percent.

Additional data from the KOA survey indicate that camping households tend to be larger than average in size. Sixty-four percent of camping households were found by KOA to contain three or more persons, as compared with the national average of 50 percent. This partially supports the contention that camping is an important family activity.

**Table 3.—Recreation use of U.S. Forest Service developed campgrounds, 1972–1977**

| Year | Visitor days (thousands) | Percent annual change |
|---|---|---|
| 1972 | 36,080 | |
| 1973 | 35,965 | −0.3 |
| 1974 | 35,678 | −0.8 |
| 1975 | 37,721 | +5.7 |
| 1976 | 37,135 | −1.6 |
| 1977 | 37,554 | +1.1 |

Source: U.S. Forest Service, 1972-1977.

**Table 4.—Trend in use of campgrounds operated by the National Park Service, 1967–1977[a]**

| Year | Number of areas reporting | Overnight stays | Percent change |
|---|---|---|---|
| 1967 | 90 | 9,309,700 | + 3.4 |
| 1968 | 88 | 9,411,100 | + 1.1 |
| 1969 | 85 | 9,049,200 | − 3.8 |
| 1970 | 87 | 9,023,800 | − 0.3 |
| 1971 | 86 | 7,934,300 | −12.1 |
| 1972 | 88 | 8,383,000 | + 5.7 |
| 1973 | 90 | 8,685,100 | + 3.6 |
| 1974 | 89 | 8,411,800 | − 3.1 |
| 1975 | 89 | 8,817,000 | + 4.8 |
| 1976 | 92 | 9,267,300 | + 5.1 |
| 1977 | 93 | 9,318,600 | + 0.6 |

[a]Total of overnight stays reported does not include campers staying at concessionaire campgrounds located in National Park Service areas. In 1976 a total of 817,638 overnight stays was recorded at concessionaire-operated trailer villages and campgrounds. An additional 3,108,690 overnight stays were tallied at rooms and cabins operated by concessionaries in National Park Service areas.

Source: National Park Service, 1978.

**Table 5.—Monthly totals of overnight stays and visits at National Park Service areas, January–October 1978**

| Month | Overnight stays | | Total visits | |
|---|---|---|---|---|
| | Number | Percent change from previous year | Number | Percent change from previous year |
| January | 358,800 | + 4.2 | 9,414,000 | + 5.0 |
| February | 427,100 | − 9.0 | 9,467,500 | −13.4 |
| March | 745,400 | +21.3 | 15,844,900 | + 6.6 |
| April | 874,900 | −19.5 | 21,681,600 | + 2.3 |
| May | 1,413,400 | − 0.9 | 25,439,900 | + 0.2 |
| June | 2,728,200 | − 1.5 | 33,195,900 | + 7.3 |
| July | 3,555,900 | − 4.0 | 44,456,100 | + 3.2 |
| August | 3,459,300 | + 0.3 | 37,974,800 | − 0.3 |
| September | 2,000,000 | +10.8 | 26,278,600 | + 6.6 |
| October | 1,090,400 | +10.4 | 22,948,700 | +12.4 |

Source: U.S. Travel Data Center, 1979.

**Table 6.—Percentage of campers with selected characteristics, compared to percentages of the general public**

| Characteristic | Percentage of U.S. public, 1975[a] | Percentage of U.S. campers, 1976[b] |
|---|---|---|
| Household income | | |
| $ 0–$ 9,999 | 42 | 29 |
| 10,000– 14,999 | 21 | 28 |
| 15,000 and over | 37 | 44 |
| Education (head of household) | | |
| Non high school graduate | 38 | 12 |
| High school graduate | 47 | 70 |
| College graduate | 16 | 18 |
| Age (head of household) | | |
| Under 25 years | 8 | 13 |
| 25–54 years | 56 | 68 |
| 55 years and older | 36 | 20 |
| Household size | | |
| 1–2 persons | 50 | 36 |
| 3–4 persons | 33 | 42 |
| 5 or more persons | 17 | 22 |

[a]U.S. Bureau of the Census 1976.

[b]Kampgrounds of America, 1976. In 1976 KOA mailed 5,000 questionnaires to a sample of U.S. families. Eighty percent of the questionnaires were returned.

According to KOA survey statistics, 88 percent of all camping household heads have been graduated from high school at least. This compares with 63 percent for the total U.S. public. Survey findings also indicate that heads of camping households are younger than noncampers. Whereas 36 percent of all U.S. heads of household are 55 years or older, only 20 percent of camping heads of households have reached the age of 55 years.

*Geographic distribution of campers.* Findings from the NEM-42 (Bond et al. 1973, Kottke et al. 1977) and the 1977 American Forest Institute Recreation Survey show an increase between 1973 and 1977 in the percentage of campers coming from the North-

east and North Central states (Table 7). In contrast, the number of U.S. campers coming from the South and West appears to have decreased as a percentage of the total in the same years.

When 1975 total population levels are compared with 1977 Woodall campsite supply data, the Northeast has a higher number of residents per campsite (333 persons per campsite) than any other region and significantly more than the national average (228) (Table 7). The reverse is seen in the West, where a resident population of 154 persons exists for every campsite listed in the Woodall directory.

Although these statistics indicate that disparities may exist between regions in the number of developed campsites available to the resident population of that region, the substantial amount of travel traditionally undertaken by campers makes any determination of appropriate regional campsite supply levels unrealistic.

Data from the 1976 National Travel Survey (U.S. Travel Data Center 1977) indicate that camping was involved to some degree in 64 million person-trips taken by U.S. travelers in 1976. The most popular camping destination regions were the Far West and Hawaii and the South; the fewest camping trips were taken in the New England and Eastern Gate-

**Table 7.—Residence of U.S. campers by census region, 1973 and 1977**

| Census region | Active campers | | | Regional population per site available[d] |
|---|---|---|---|---|
| | 1975 U.S. population[a] | 1973 NEM-42[b] | 1977 AFI[c] | |
| | *Percent* | | | |
| Northeast | 23 | 14 | 17 | 333 |
| North Central | 27 | 23 | 33 | 206 |
| South | 32 | 31 | 21 | 263 |
| West | 18 | 32 | 28 | 154 |
| U.S. total | 100 | 100 | 99 | 228 |

[a]Based on 1975 U.S. Bureau of the Census population statistics.
[b]Kottke et al. 1975:10.
[c]American Forest Institute 1977:12.
[d]Based on 1975 Bureau of the Census population data and 1977 Woodall's Campground Directory statistics.

**Table 8.—Origin and destination of camping trips by travel region, 1976**

| Travel region[a] | Number of camping trips | | Difference |
|---|---|---|---|
| | Origin | Destination | |
| New England | 2,478 | 2,492 | + 14 |
| Eastern Gateway | 6,007 | 3,600 | −2,407 |
| G. Washington Country | 6,767 | 6,041 | − 726 |
| South | 9,209 | 12,825 | +3,616 |
| Great Lakes Country | 12,804 | 9,012 | −3,792 |
| Mountain West | 4,072 | 4,480 | + 408 |
| Frontier West | 7,799 | 7,492 | − 307 |
| Far West and Hawaii | 15,047 | 15,141 | + 94 |
| Outside U.S. | — | 3,099 | — |
| Total | 64,183 | 64,182 | — |

[a]For a disaggregation of travel regions, see Appendix, p. 35.
Source: U.S. Travel Data Center 1977.

way travel regions (Table 8). The "import-export" balance of campers was most disproportionate in the Great Lakes Country and Eastern Gateway (greater export) and the South (greater import).

### Equipment and facility use and preference

*Preferred type of camping shelter.* Comparative findings from three camping surveys conducted between 1971 and 1976 indicate that tents and recreational vehicles (RV's) were equally popular in 1971. However, in 1973 and 1976, RV's were more popular than tents (Table 9).

There is, however, some indication that tents may be regaining some of their former popularity. Findings from the 1973 survey show that 41 percent of active campers used tents, and statistics from the 1976 survey place the percentage of active tent campers at 43 percent. This slight but potentially significant increase in tent use is partially supported by the 1973 survey finding that a majority (59 percent) of noncampers who planned to camp for the first time in 1974 indicated that they would use tents.

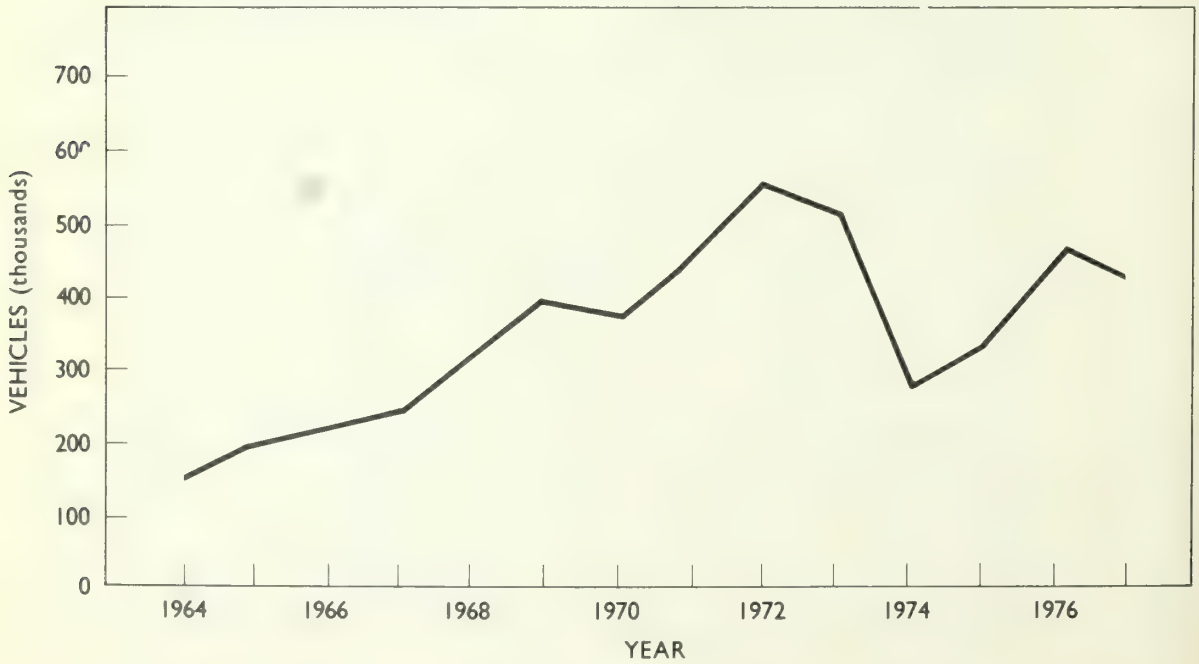
*Recreation vehicle shipments.* While survey findings suggest some increase in the use of tents, recent RV shipments from manu-

**Table 9.—Preferred type of camping shelter, 1971, 1973, and 1976**

| Shelter type | Percent of all campers | | |
|---|---|---|---|
| | 1971[a] | 1973[b] | 1976[c] |
| Tent | 50 | 41 | 43 |
| Tent trailer | 13 | 11 | 13 |
| Travel trailer | 17 | 17 | 17 |
| Truck camper | 15 | 15 | 15 |
| Motor home | 3 | 7 | 7 |
| Van or converted bus | 6 | 10 | 6 |
| Pick-up cover | 6 | 5 | — |
| Other | — | 5 | 6 |
| Unknown | — | 1 | 1 |

[a]LaPage 1973:4.
[b]Kottke et al. 1975:16.
[c]Kampgrounds of America 1976:1.

**Figure 1.—Recreational vehicle shipments, 1964–1977. Shipments do not include pick-up covers and type B2 motor homes ("surfer vans"). Source: Recreation Vehicle Industry Association, 1976–1978.**



facturers to dealers have declined. During 1977, 414 thousand new RV's were shipped to U.S. dealers—a decrease of 6 percent from 1976 shipments (Figure 1, Table 10). RV shipments do not include pickup covers and type B2 motor homes ("surfer vans"—minimum life support).

Although the gasoline shortage early in the year undoubtedly contributed to a 30 percent decrease in total RV shipments in 1974, deliveries began to increase in late 1974—a trend that ended in 1976. Between 1976 and 1977, shipments of truck campers decreased by 24 percent and shipments of travel trailers by 12 percent. Only slight increases occurred in motor home (+3 percent) and camping trailer (+2 percent) shipments. David Forward, President of the Recreation Vehicle Industry Association (RVIA), attributed the slump in 1977 RV sales to the effects of President Carter's energy message in April 1977. However, according to Forward, RV sales began a comeback; by the end of 1977, sales figures were higher than for the same period in 1976 (Los Angeles Times 1977).

The National Park Service (NPS) has compared RV and tent use in the period from 1965 to 1976 (Figure 2). Since 1971 RV's have been more common than tents at NPS-operated campgrounds. In 1977 approximately 57 percent of NPS campers used RV's, and 43 percent used tents. Between 1976 and 1977 the number of RV campers staying at NPS campgrounds declined slightly, whereas the number of NPS tent campers increased slightly. Also, during the 1974 energy crisis the number of NPS tent campers decreased less than NPS recreational vehicle campers. This may indicate that during periods of unusually high gas prices or gas shortages, tent camping becomes more popular.

*Relationship between nights camped and equipment used.* RV's not only appear to be more popular than tents but are also used more (Figure 3). Tent campers averaged 9 nights for the season, while motor home users averaged 23. As a group, RV campers averaged 16 nights of camping per year. Quite possibly, a greater fixed investment in equipment is associated with a desire to utilize such equipment more fully.

*Income of campers.* A KOA analysis of in-

**Table 10.—Recreational vehicle shipments, 1961–1977 (thousands)[a]**

| Year | Camping trailers | Truck campers | Motor homes | Travel trailers | Total shipments | Percent change from preceding year |
|---|---|---|---|---|---|---|
| 1961 | 18 | 16 | — | 29 | 63 | — |
| 1962 | 23 | 17 | — | 41 | 80 | +27.0 |
| 1963 | 40 | 27 | — | 52 | 119 | +48.8 |
| 1964 | 52 | 35 | — | 64 | 151 | +26.9 |
| 1965 | 67 | 44 | 5 | 77 | 193 | +24.5[b] |
| 1966 | 72 | 55 | 6 | 87 | 220 | +14.0 |
| 1967 | 79 | 62 | 9 | 95 | 244 | +10.9 |
| 1968 | 125 | 80 | 13 | 115 | 333 | +36.5 |
| 1969 | 141 | 93 | 23 | 144 | 401 | +20.4 |
| 1970 | 116 | 96 | 30 | 138 | 380 | − 5.2 |
| 1971 | 96 | 107 | 57 | 191 | 451 | +18.7 |
| 1972 | 110 | 105 | 117 | 251 | 583 | +29.3 |
| 1973 | 98 | 90 | 129 | 212 | 529 | − 9.3 |
| 1974 | 55 | 45 | 69 | 126 | 296 | −44.1 |
| 1975 | 48 | 44 | 97 | 151 | 340 | +14.9 |
| 1976 | 53 | 42 | 156 | 190 | 441 | +29.7 |
| 1977 | 54 | 32 | 160 | 168 | 414 | − 6.1 |

[a]Shipments do not include pick-up covers and type B2 motor homes ("surfer vans").
[b]Motor homes are not included in this calculation
Source: Recreation Vehicle Industry Association 1977, 1978.

Figure 2.—Tent and recreational vehicle used in campgrounds operated by the National Park Service, 1965–1977.
Source: U.S. National Park Service, 1978.

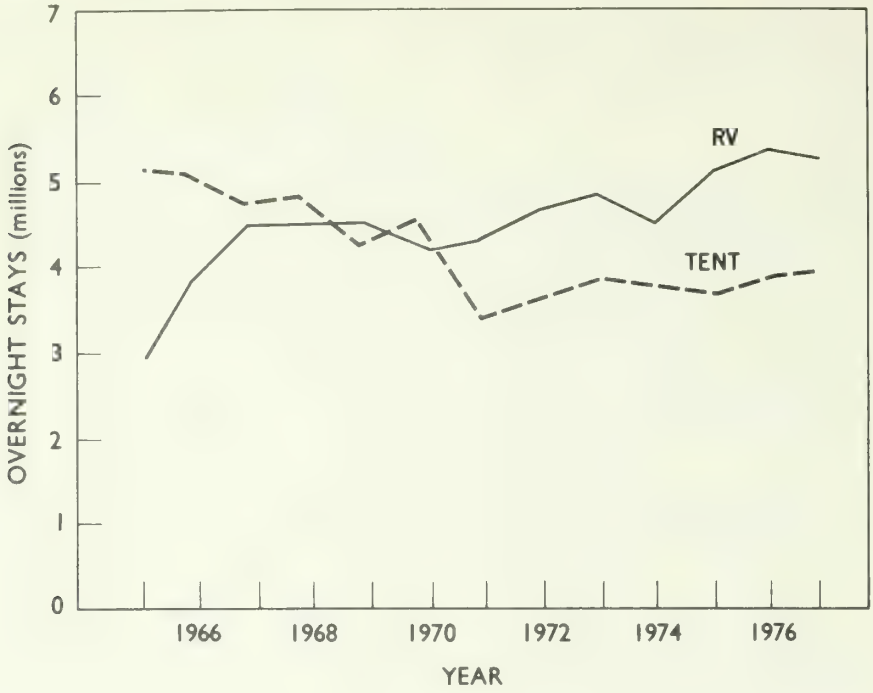
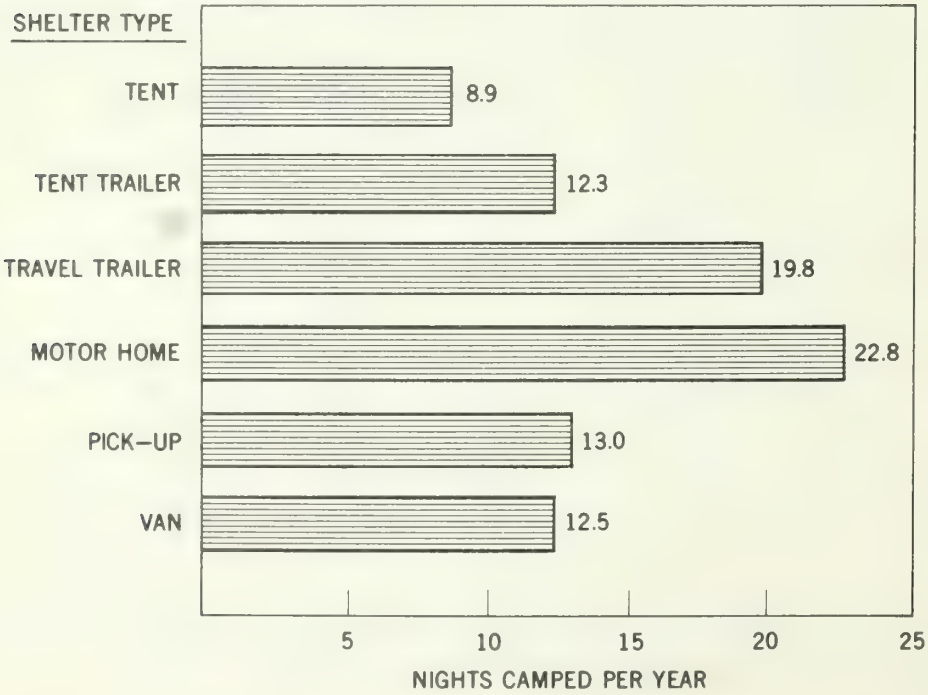



Figure 3.—Average number of nights camped by campers using various types of shelter, 1976.
Source: Kampgrounds of America, 1976.



come earned by RV owners and tenters shows little difference between the two groups (Figure 4). Of campers responding to the KOA survey, 42 percent of tent campers and 44 percent of RV campers reported household incomes in excess of $15,000. Brokaw and Cole (1977) analyzed the relationship between income and desired level of campground development (Table 11). They found that Delaware state park campers as a group preferred a combination of picnic tables, firewood, level parking, water, flush toilets, showers, and minimal activity development. Campers earning more than $10,000 a year preferred a lesser degree of development than those whose income was under $10,000.

**Figure 4.—Household income of RV and tent campers, 1976. Source: Kampgrounds of America, 1976.**

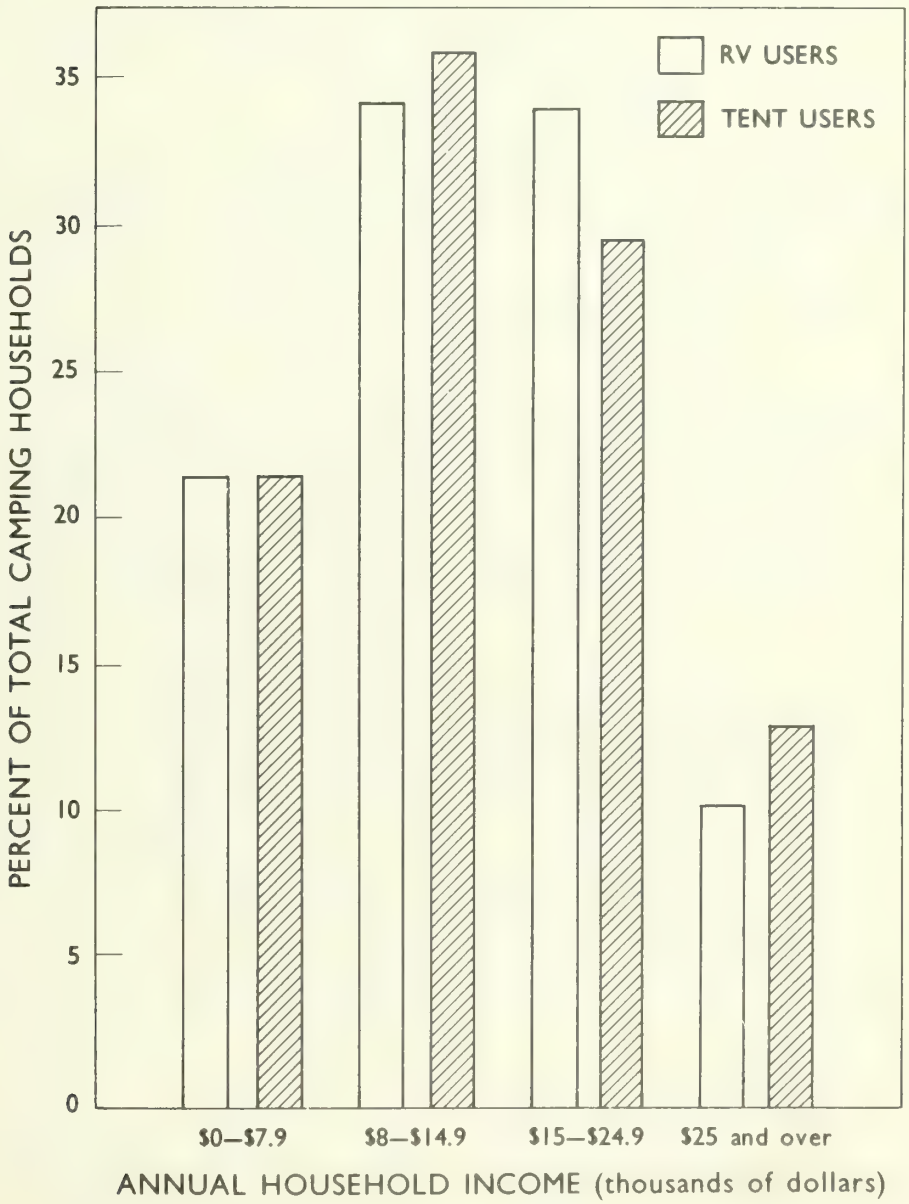


**Table 11.—Percentage of campers who prefer various levels of campground development, by income of campers, Delaware, 1975**

| Income | Facility groups[a] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | I Least developed | II | III | IV | V | VI | VII Most developed | Total |
| Under $6,000 | 0.0 | 22.2 | 33.3 | 11.2 | 33.3 | 0.0 | 0.0 | 100.0 |
| $ 6,000– 9,999 | 10.0 | 23.3 | 20.0 | 20.0 | 23.3 | 0.0 | 3.4 | 100.0 |
| $10,000–14,999 | 15.9 | 34.9 | 11.1 | 15.9 | 12.7 | 6.3 | 3.2 | 100.0 |
| $15,000–24,999 | 10.2 | 37.2 | 13.6 | 8.5 | 16.9 | 8.5 | 5.1 | 100.0 |
| $25,000 and over | 0.0 | 23.5 | 23.5 | 11.9 | 17.6 | 17.6 | 5.9 | 100.0 |
| Combined income groups | 10.7 | 32.0 | 15.7 | 13.5 | 17.4 | 6.8 | 3.9 | 100.0 |

[a]Facility development groups are as follows:

Group I—Water, picnic tables; no recreational facility development in the campground.

Group II—Water, showers, flush toilets, picnic tables, level campsites, and firewood; minimal activity development. May or may not include security patrol.

Group III—Electricity and water hookup. Minimal activity development.

Group IV—Group II features plus electric hookup.

Group V—Three way hookup. Minimal activity development.

Group VI—Group II features plus extensive development, including swimming pool, sports areas, store, laundry, and playground.

Group VII—All the features of Group VI plus destination-oriented activities similar to Disney World.

Source: Brokaw and Cole, 1977.

## Energy and economic situation

*The energy situation and camping.* In response to President Carter's presentation of a national energy policy on April 20, 1977, the Executive Director of the North American Family Campers Association (NAFCA) wrote to the President:

> Yes, energy conservation is crucial, but an undue burden placed on camping vehicle owners and not shared equitably by other large users of petroleum products, would not only be unfair, but could seriously curtail enjoyment of the great outdoors by some 50 million American campers . . . NAFCA will encourage the planning of camping trips that will require fewer annual miles and at lower highway speeds.

The Federal Energy Administration responded to NAFCA by saying, basically, that the President's energy proposals would not disproportionately affect the leisure camping industry, the idea being not to discourage activity of this kind but merely to provide "incentives" for doing it more economically (i.e., incentives against lower mile-per-gallon vehicles, such as campers, could be expected).

A study conducted by the Opinion Research Corporation in 1977 for the U.S. Bureau of Outdoor Recreation (USDI) measured changing recreational habits in this time of voluntary energy conservation. According to this study, the recreational habits of 76 percent of U.S. Forest recreation area users were unaffected by the prevailing energy situation. Among the 24 percent whose habits had changed, equal numbers cited (1) increased transportation costs and (2) desire to conserve fuel as the reasons for change.

The 1977 NE-100 study[1] of recreational patterns shows that Northeastern campers are traveling farther from home than they did a few years ago (Table 12). In fact, the percentage of campers who traveled farther was twice that of those who camped closer to home.

The 1976 National Travel Survey (U.S. Travel Data Center 1977) shows that camping trips are longer in terms of miles than other types of trips taken by Americans

[1]NE-100 Technical Research Committee, Northeastern States Agricultural and Forestry Experiment Stations. December 1977. Preliminary unpublished data. Results are based on telephone interviews with 3,900 persons in the northeastern states.

**Table 12.—Change in distance traveled from home location to campsite, Northeastern states campers, 1977 study (in percent of participants)**

| Type of camping | Location of place most often camped in last 2 years | | |
|---|---|---|---|
| | No change | Closer to home | Farther from home |
| Backpack | 46 | 16 | 38 |
| Tent | 48 | 16 | 36 |
| Recreation vehicle | 51 | 17 | 32 |

Source: NE-100 Technical Research Committee, Northeastern States Agricultural Experiment Stations. 1977. Unpublished data.

(Table 13). About 66 percent of all camping trips involved more than 400 miles of round-trip travel; only 62 percent of all trips fell in this range. Twenty-six percent of camping trips involved more than 1,000 miles of travel, compared with 22 percent of all trips.

*The economic situation and travel.* The U.S. economy experienced a recession in 1975, unemployment reached a high of 8.5 percent, and consumer purchases of goods and services stagnated (in constant dollars) (U.S. Bureau of the Census 1976). The economy experienced a return to more normal conditions in 1976, with a real gain in the gross national product of 6.1 percent over 1975 (adjusted for inflation). As a result, purchases of goods and services increased 9.6 percent over 1975 levels (Marketing Handbooks 1978:87).

Looking at the longer-range trends (1966 to 1976), the aggregate annual income of the lower middle–class worker ($5,000 to $15,000) grew at a slower rate than the income of persons in higher economic classes. Travel experts believe that the $5,000 to $15,000 sector holds the greatest potential for growth in the travel industry (Marketing Handbooks 1978:87). Quite possibly, income tax reform measures will accelerate such growth. How and where persons in the lower middle class spend travel funds will depend in part on the relative cost of accommodations—a factor with major implications for the camping industry.

## SUPPLY SITUATION FOR DEVELOPED CAMPING

### Number of campsites and campgrounds—private inventories

No one can confidently say how many developed campsites exist in the public and private sectors of the nation's campground industry. Lack of accurate campsite enumeration data can be attributed to many factors, including the dynamics of the camping industry and the lack of a reliable, recurring camping supply inventory.

**Table 13.—Number of camping-related person-trips categorized by distance traveled, 1976[a]**

| Round-trip miles | All trips | | Camping trips | |
|---|---|---|---|---|
| | Thousand | Percent | Thousand | Percent |
| 200– 299 | 136,937 | 19.4 | 10,356 | 16.1 |
| 300– 399 | 129,499 | 18.4 | 11,402 | 17.8 |
| 400– 599 | 139,987 | 19.8 | 13,777 | 21.5 |
| 600– 999 | 117,301 | 16.6 | 8,720 | 13.6 |
| 1,000–1,999 | 79,750 | 11.3 | 7,882 | 12.3 |
| 2,000 and over | 73,895 | 10.5 | 8,947 | 13.9 |
| Outside U.S. | 28,339 | 4.0 | 3,099 | 4.8 |
| Total | 705,708 | 100.0 | 64,183 | 100.0 |

[a]A person-trip results when one person takes one trip. Thus, a family of four taking a trip together would count as four person-trips.

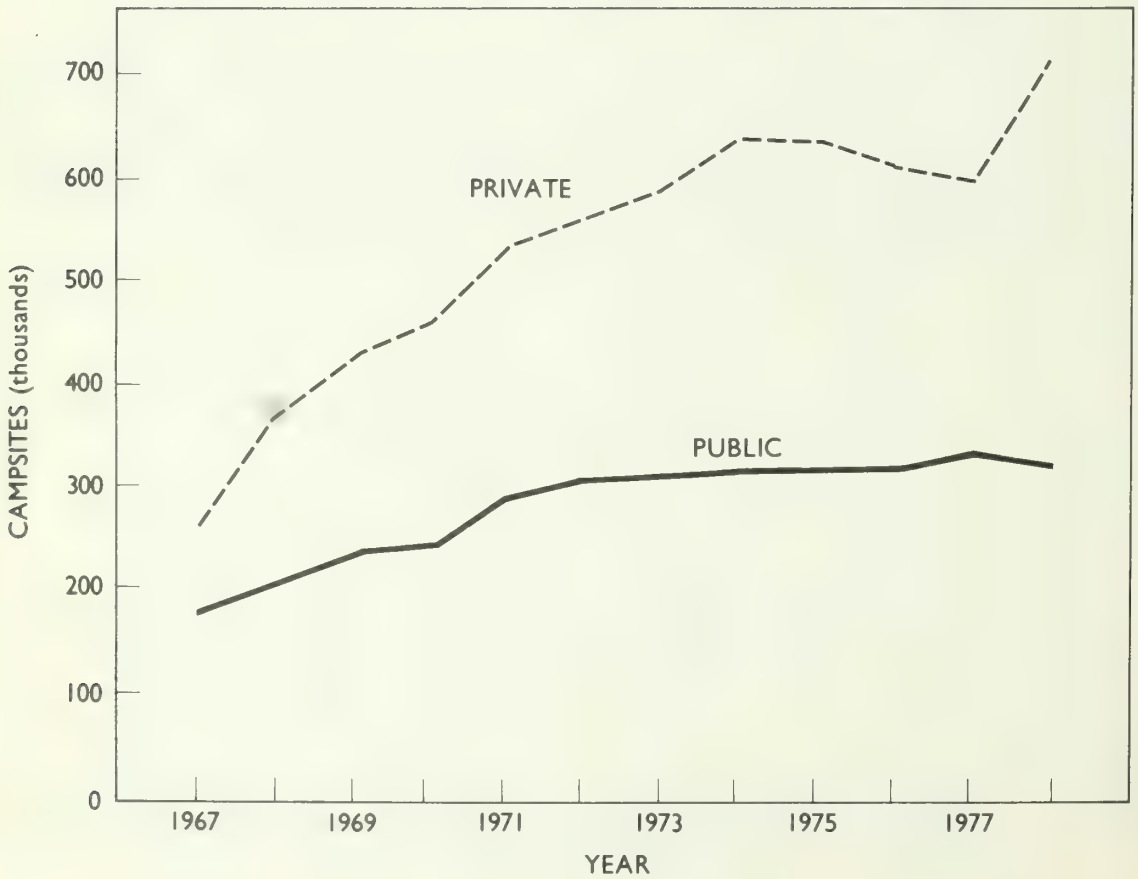
Source: U.S. Travel Data Center 1977:34, 103.

**Table 14.—Developed campsites in the United States, 1967–1978, as listed in the Woodall directory**

| Year | Campsites | | | Annual change in total sites |
|---|---|---|---|---|
| | Public | Private | Total | |
| | | *Thousands* | | *Percent* |
| 1967 | 177 | 267 | 444 | |
| 1968 | 205 | 373 | 578 | +30.2 |
| 1969 | 230 | 403 | 633 | + 9.5 |
| 1970 | 247 | 442 | 689 | + 8.9 |
| 1971 | 286 | 515 | 801 | +16.3 |
| 1972 | 306 | 562 | 868 | + 8.4 |
| 1973 | 306 | 584 | 890 | + 2.5 |
| 1974 | 321 | 644 | 965 | + 8.4 |
| 1975 | 322 | 643 | 965 | 0.0 |
| 1976 | 322 | 612 | 934 | − 3.2 |
| 1977 | 333 | 600 | 933 | − 0.1[a] |
| 1978 | 311 | 717 | 1028 | +10.2[a] |

[a]Woodall management has indicated that the 1977 private sector inventory may have been low because of slightly different criteria used to identify campgrounds that should be listed.

**Figure 5.—Public and private developed campsites in the United States. Woodall management has indicated that 1977 private campsite numbers may be low because of changes in campground inventory procedures and not because there were fewer private campgrounds.)**



*NACD inventory.* One recent attempt to improve information of the Nation's supply of recreation resources and opportunities was made by the National Association of Conservation Districts (NACD).[2] Findings from this national survey indicated that in 1974 transient and vacation camping areas operated by the private sector contained a total of 886,544 RV sites and 538,168 tent sites.

*Woodall Directory.* Although the exact number of developed campsites is unavailable, a rough but useful estimate may be made from published campground directories. *Woodall's Campground Directory* is published annually and lists those campgrounds that have a minimum of 10 recreational vehicle (RV) sites, provide drinking water, and meet Woodall's standards for cleanliness. Woodall listings indicate that between 1967 and 1973 there was an increase of 119 percent (an average of 20 percent per year) in the number of private campsites nationally, and an increase of 73 percent (an average of 12 percent per year) in public campsites (Table 14, Figure 5). Between 1973 and 1978 there was an increase of 23 percent (an average of 5 percent per year) in the number of private campsites and an increase of 2 percent (less than 1 percent per year) in public campsites. These trends are graphically presented in Figure 5. Without question, the rate of growth on the supply side is lower now than in the late sixties and early seventies.

*Rand McNally Directory.* Another source of camping supply statistics is the Rand McNally Campground Guide. Like the Woodall statistics, the Rand McNally summaries show significant growth in campgrounds during the sixties and early seventies, followed by a relatively stable situation in both public and private sectors in the mid-seventies. Both Rand McNally and Woodall data show that between 1973 and 1978 the number of private campgrounds decreased by approximately 10 percent (Table 15). However, Rand McNally and Woodall disagree on the trend in public campground development. For the period from 1973 to 1978 Rand McNally data indicate that public campgrounds *increased* by more than 25 percent; however, Woodall statistics show that the number of public campgrounds *decreased* by more than 27 percent. It is not known which of these two sources more accurately describes the supply of campgrounds in the United States.

*Geographic distribution of supply.* The geographic distribution of U.S. campgrounds in 1973 and 1978 is shown in Table 16. Significant differences are seen in Woodall and Rand McNally data, especially in the number of campgrounds in the Western states. However, looking at each region as a percentage of the total U.S. supply (Table 17), one sees similarities in the Woodall and Rand McNally statistics, especially in the listing of private areas.

### Number of campsites and campgrounds—public inventories

*U.S. Forest Service.* An indication of recent stability in the camping supply situation is seen in an analysis of developed U.S. Forest Service camping areas. Over the past 6 pears there have been only minor fluctuations in the capacity of such areas (Table 18). From 1972 to 1977 the annual change in Forest Service campground capacity was one percent or less.

*National Park Service.* Following decreases in 1974 and 1975, the estimated number of campsites operated by the National Park Service (NPS) increased modestly in 1976 (Table 19). The number of NPS campsites does not include those operated by concessionaires on National Park Service lands. (See also footnotes to Table 20.) The establishment of carrying capacity limits at selected National Park Service areas resulted in the elimination of some individual campsites.

*U.S. Army Corps of Engineers.* Camping areas managed by the Corps increased by 17 percent from 1974 to 1977 (Table 20), a growth rate almost twice that of Corps-managed day-use areas.

[2]National Association of Conservation Districts. 1977. Inventory of private recreation facilities, 1977. League City, Tex. The NACD inventory was administered individually by each state NACD organization and included both profit and nonprofit recreation operations of the private sector. Figures do not include Puerto Rico, Texas, or the Virgin Islands.

**Table 15.—Percent change in campground numbers between 1973 and 1978, by census region and state (Rand McNally and Woodall directories)**

| Census region/state | Rand McNally | | Woodall | |
|---|---|---|---|---|
| | Public | Private | Public | Private |
| NORTHEAST | + 56.1 | + 0.4 | − 8.3 | −14.7 |
| New England | + 54.0 | − 6.2 | −23.5 | −11.0 |
| Connecticut | + 44.4 | + 15.6 | − 6.7 | +20.0 |
| Maine | + 53.5 | − 15.1 | −38.9 | −27.1 |
| Massachusetts | + 65.2 | + 8.4 | + 4.2 | − 1.9 |
| New Hampshire | + 83.3 | − 5.8 | −36.7 | − 2.4 |
| Rhode Island | +125.0 | − 11.1 | +75.0 | −20.0 |
| Vermont | + 25.6 | − 7.5 | −32.5 | − 3.8 |
| Middle Atlantic | + 57.6 | + 5.6 | + 3.7 | −17.2 |
| New Jersey | + 5.0 | + 14.5 | 0.0 | − 3.4 |
| New York | + 63.4 | + 2.2 | + 7.4 | −14.1 |
| Pennsylvania | + 62.8 | + 6.5 | 0.0 | −24.0 |
| NORTH CENTRAL | + 34.5 | + 2.3 | −19.4 | − 6.0 |
| East North Central | + 33.8 | + 9.8 | −17.5 | − 0.4 |
| Illinois | + 60.2 | − 3.6 | − 9.6 | − 5.1 |
| Indiana | + 67.7 | + 0.6 | +16.4 | −11.8 |
| Michigan | + 28.9 | + 26.5 | −27.1 | +33.7 |
| Ohio | + 70.5 | + 13.0 | −10.0 | − 9.5 |
| Wisconsin | + 6.0 | + 6.2 | −15.6 | − 8.3 |
| West North Central | + 35.1 | − 9.2 | −21.0 | −14.1 |
| Iowa | + 5.4 | − 24.6 | −40.4 | −30.8 |
| Kansas | +156.3 | − 19.7 | −22.2 | −24.7 |
| Minnesota | + 28.8 | − 5.8 | − 6.5 | −12.2 |
| Missouri | + 46.1 | − 9.4 | +11.7 | + 6.0 |
| Nebraska | + 11.0 | − 7.4 | +11.0 | −19.4 |
| North Dakota | + 13.7 | − 10.5 | −19.8 | −28.1 |
| South Dakota | + 21.9 | − 3.2 | −50.0 | −23.1 |
| SOUTH | + 42.1 | − 11.1 | −11.7 | −12.1 |
| South Atlantic | + 54.8 | − 3.0 | − 9.0 | −16.8 |
| Delaware | + 20.0 | + 28.6 | 0.0 | −20.0 |
| Florida | + 74.0 | + 2.4 | −24.4 | −22.7 |
| Georgia | + 34.8 | − 34.7 | −31.8 | −20.0 |
| Maryland | + 43.8 | + 8.0 | −17.4 | − 3.8 |
| North Carolina | + 60.7 | − 14.3 | + 3.8 | −10.1 |
| South Carolina | + 59.3 | − 23.8 | − 2.2 | −22.7 |
| Virginia | + 71.4 | + 19.3 | +11.1 | − 9.9 |
| West Virginia | + 39.3 | + 41.0 | +15.9 | + 8.5 |
| SOUTH | | | | |
| East South Central | + 50.0 | − 10.8 | − 7.5 | −22.7 |
| Alabama | + 69.8 | − 19.1 | −20.6 | −44.9 |
| Kentucky | + 54.7 | + 14.7 | 0.0 | − 8.6 |
| Mississippi | + 22.2 | − 13.2 | −11.9 | −34.5 |
| Tennessee | + 55.4 | − 18.1 | − 6.8 | − 9.6 |
| West South Central | + 29.4 | − 26.6 | −15.4 | + 2.8 |
| Arkansas | + 27.7 | − 17.2 | −42.6 | +32.2 |
| Louisiana | + 82.6 | − 25.0 | −25.0 | −48.4 |
| Oklahoma | + 19.6 | − 22.8 | −44.5 | −25.4 |
| Texas | + 32.7 | − 29.4 | +34.0 | +33.7 |
| WEST | + 12.7 | − 26.3 | −42.5 | −12.5 |
| Mountain | + 14.7 | − 28.9 | −39.5 | −11.3 |
| Arizona | + 37.8 | − 34.6 | + 8.2 | 0.0 |
| Colorado | + 16.1 | − 27.1 | −20.8 | − 8.9 |
| Idaho | + 9.6 | − 27.9 | −81.9 | −30.8 |

Continued

**Table 15.—Continued**

| Census region/state | Rand McNally | | Woodall | |
|---|---|---|---|---|
| | Public | Private | Public | Private |
| Montana | + 5.9 | − 10.6 | −26.4 | −20.2 |
| Nevada | + 33.3 | + 6.4 | −37.9 | + 6.0 |
| New Mexico | + 5.9 | − 45.0 | − 8.2 | − 4.0 |
| Utah | + 18.2 | − 39.8 | −53.0 | − 2.9 |
| Wyoming | + 9.2 | − 33.1 | −58.7 | −28.1 |
| Pacific | + 10.9 | − 23.8 | −45.2 | −13.6 |
| Alaska | + 22.5 | + 26.7 | −29.9 | −31.8 |
| California | + 11.5 | − 30.5 | −38.5 | − 0.3 |
| Hawaii | + 63.2 | −100.0 | −30.5 | 0.0 |
| Oregon | + 3.9 | − 28.3 | −61.5 | −33.9 |
| Washington | + 10.6 | + 1.9 | −45.9 | −18.6 |
| UNITED STATES | + 25.7 | − 10.1 | −27.8 | −11.2 |

**Table 16.—Number of campgrounds in each census region and state, 1973 and 1978 (Rand McNally and Woodall directories)**

| Census region/state | Rand McNally | | | | Woodall | | | |
|---|---|---|---|---|---|---|---|---|
| | Public | | Private | | Public | | Private | |
| | 1973 | 1978 | 1973 | 1978 | 1973 | 1978 | 1973 | 1978 |
| NORTHEAST | 371 | 579 | 1,575 | 1,581 | 336 | 308 | 1,733 | 1,478 |
| New England | 161 | 248 | 692 | 649 | 149 | 114 | 692 | 616 |
| Connecticut | 18 | 26 | 45 | 52 | 15 | 14 | 50 | 60 |
| Maine | 43 | 66 | 252 | 214 | 36 | 22 | 266 | 194 |
| Massachusetts | 23 | 38 | 95 | 103 | 24 | 25 | 104 | 102 |
| New Hampshire | 30 | 55 | 189 | 178 | 30 | 19 | 167 | 163 |
| Rhode Island | 4 | 9 | 18 | 16 | 4 | 7 | 25 | 20 |
| Vermont | 43 | 54 | 93 | 86 | 40 | 27 | 80 | 77 |
| Middle Atlantic | 210 | 331 | 883 | 932 | 187 | 194 | 1,041 | 862 |
| New Jersey | 20 | 21 | 110 | 126 | 17 | 17 | 119 | 115 |
| New York | 112 | 183 | 405 | 414 | 95 | 102 | 468 | 402 |
| Pennsylvania | 78 | 127 | 368 | 392 | 75 | 75 | 454 | 345 |
| NORTH CENTRAL | 1,777 | 2,390 | 2,047 | 2,094 | 1,980 | 1,596 | 2,278 | 2,142 |
| East North Central | 820 | 1,097 | 1,241 | 1,362 | 898 | 741 | 1,354 | 1,348 |
| Illinois | 103 | 165 | 167 | 161 | 83 | 75 | 175 | 166 |
| Indiana | 65 | 109 | 174 | 175 | 67 | 78 | 211 | 186 |
| Michigan | 356 | 459 | 260 | 329 | 409 | 298 | 267 | 357 |
| Ohio | 78 | 133 | 254 | 287 | 70 | 63 | 316 | 286 |
| Wisconsin | 218 | 231 | 386 | 410 | 269 | 227 | 385 | 353 |
| West North Central | 957 | 1,293 | 806 | 732 | 1,082 | 855 | 924 | 794 |
| Iowa | 185 | 195 | 69 | 52 | 292 | 174 | 117 | 81 |
| Kansas | 103 | 264 | 66 | 53 | 180 | 140 | 73 | 55 |
| Minnesota | 233 | 300 | 344 | 324 | 170 | 159 | 319 | 280 |
| Missouri | 102 | 149 | 160 | 145 | 94 | 105 | 199 | 211 |
| Nebraska | 127 | 141 | 54 | 50 | 118 | 131 | 67 | 54 |
| North Dakota | 102 | 116 | 19 | 17 | 106 | 85 | 32 | 23 |
| South Dakota | 105 | 128 | 94 | 91 | 122 | 61 | 117 | 90 |
| SOUTH | 1,453 | 2,065 | 2,223 | 1,977 | 1,232 | 1,088 | 2,473 | 2,175 |
| South Atlantic | 498 | 771 | 1,246 | 1,209 | 399 | 363 | 1,366 | 1,137 |
| Delaware | 5 | 6 | 14 | 18 | 4 | 4 | 20 | 16 |
| Florida | 96 | 167 | 551 | 564 | 82 | 62 | 611 | 472 |
| Georgia | 112 | 151 | 150 | 98 | 85 | 58 | 130 | 104 |

Continued

**Table 16.—Continued**

| Census region/state | Rand McNally | | | | Woodall | | | |
|---|---|---|---|---|---|---|---|---|
| | Public | | Private | | Public | | Private | |
| | 1973 | 1978 | 1973 | 1978 | 1973 | 1978 | 1973 | 1978 |
| Maryland | 32 | 46 | 50 | 54 | 23 | 19 | 52 | 50 |
| North Carolina | 61 | 98 | 217 | 186 | 52 | 54 | 247 | 222 |
| South Carolina | 54 | 86 | 80 | 61 | 46 | 45 | 88 | 68 |
| Virginia | 77 | 132 | 145 | 173 | 63 | 70 | 171 | 154 |
| West Virginia | 61 | 85 | 39 | 55 | 44 | 51 | 47 | 51 |
| East South Central | 284 | 426 | 323 | 288 | 254 | 235 | 392 | 303 |
| Alabama | 43 | 73 | 68 | 55 | 34 | 27 | 107 | 59 |
| Kentucky | 86 | 133 | 68 | 78 | 87 | 87 | 81 | 74 |
| Mississippi | 63 | 77 | 38 | 33 | 59 | 52 | 58 | 38 |
| Tennessee | 92 | 143 | 149 | 122 | 74 | 69 | 146 | 132 |
| West South Central | 671 | 868 | 654 | 480 | 579 | 490 | 715 | 735 |
| Arkansas | 184 | 235 | 87 | 72 | 162 | 93 | 118 | 80 |
| Louisiana | 23 | 42 | 92 | 69 | 20 | 15 | 126 | 65 |
| Oklahoma | 189 | 226 | 57 | 44 | 191 | 106 | 67 | 50 |
| Texas | 275 | 365 | 418 | 295 | 206 | 276 | 404 | 540 |
| WEST | 3,894 | 4,387 | 2,422 | 1,784 | 2,913 | 1,676 | 2,706 | 2,369 |
| Mountain | 1,791 | 2,055 | 1,212 | 862 | 1,399 | 847 | 1,320 | 1,171 |
| Arizona | 172 | 237 | 269 | 176 | 85 | 92 | 343 | 343 |
| Colorado | 380 | 441 | 247 | 180 | 346 | 274 | 214 | 195 |
| Idaho | 293 | 321 | 140 | 101 | 259 | 47 | 159 | 110 |
| Montana | 286 | 303 | 160 | 143 | 235 | 173 | 198 | 158 |
| Nevada | 60 | 80 | 47 | 50 | 58 | 36 | 67 | 71 |
| New Mexico | 152 | 161 | 120 | 66 | 85 | 78 | 100 | 96 |
| Utah | 253 | 299 | 108 | 65 | 181 | 85 | 104 | 101 |
| Wyoming | 195 | 213 | 121 | 81 | 150 | 62 | 135 | 97 |
| Pacific | 2,103 | 2,332 | 1,210 | 922 | 1,514 | 829 | 1,386 | 1,198 |
| Alaska | 111 | 136 | 15 | 19 | 107 | 75 | 44 | 30 |
| California | 1,029 | 1,147 | 735 | 511 | 680 | 418 | 663 | 661 |
| Hawaii | 38 | 62 | 1 | 0 | 59 | 41 | 0 | 0 |
| Oregon | 538 | 559 | 251 | 180 | 426 | 164 | 298 | 197 |
| Washington | 387 | 428 | 208 | 212 | 242 | 131 | 381 | 310 |
| UNITED STATES | 7,495 | 9,421 | 8,267 | 7,436 | 6,461 | 4,668 | 9,190 | 8,164 |

**Table 17.—Percentage of United States campgrounds in each census region, 1978 (Woodall and Rand McNally directories)**

| Census region | Woodall | | Rand McNally | |
|---|---|---|---|---|
| | Public | Private | Public | Private |
| Northeast | 7 | 18 | 6 | 21 |
| North Central | 34 | 26 | 25 | 28 |
| South | 23 | 27 | 22 | 27 |
| West | 36 | 29 | 47 | 24 |
| U.S. total | 100 | 100 | 100 | 100 |

**Table 18.—Capacity of U.S. Forest Service developed camping areas, 1972–1977**

| Year | Capacity (PAOT)[a] | Annual change |
|---|---|---|
| | | *Percent* |
| 1972 | 425,144 | — |
| 1973 | 424,424 | −0.2 |
| 1974 | 424,869 | +0.1 |
| 1975 | 429,054 | +1.0 |
| 1976 | 431,616 | +0.6 |
| 1977 | 429,337 | −0.5 |

[a]The Forest Service measures capacity in terms of the number of persons who can be accommodated at one time (PAOT) at a particular area. Includes both family- and group campgrounds.

Source: U.S. Forest Service, 1972-1977.

**Table 19.—Number of National Park Service–operated campsites, 1967–1976[a]**

| Year | Number of areas reporting | Number of campsites | Annual change |
|---|---|---|---|
| | | | *Percent* |
| 1967 | 90 | 28,526 | +0.1 |
| 1968 | 88 | 28,426 | −0.4 |
| 1969 | 85 | 27,061 | −4.8 |
| 1970 | 87 | 27,648 | +2.2 |
| 1971 | 86 | 27,700 | +0.2 |
| 1972 | 88 | 27,568[b] | −0.5 |
| 1973 | 90 | 29,489 | +7.0 |
| 1974 | 89 | 29,241 | −0.8 |
| 1975 | 89 | 28,987 | −0.9 |
| 1976 | 92 | 29,676 | +2.4 |

[a]According to the National Park Service, the number of campsites is not exact and should be used only as an estimate. The combined total for types A and B campsites is used in this table. Type A campsites are located in campgrounds and include parking, grills, and picnic tables. Type B campsites are located in areas other than campgrounds and are generally of a more rustic character.

[b]An additional 2,073 sites were unidentified as to type and may have been type A or B.

Source: National Park Service, 1976, 1977.

**Table 20.—Number of recreation areas managed by the Corps of Engineers, 1974–1977**

| Type of area | Number of areas | | | | Percent change 1974–1977 |
|---|---|---|---|---|---|
| | 1974 | 1975 | 1976 | 1977 | |
| Day-use areas | 1,063 | 1,078 | 1,142 | 1,163 | + 9.4 |
| Overnight areas | 869 | 924 | 982 | 1,020 | +17.4 |
| Total | 1,932 | 2,002 | 2,124 | 2,183 | +13.0 |

Source: U.S. Army Corps of Engineers, 1975 and 1976–1977.

### Campground size

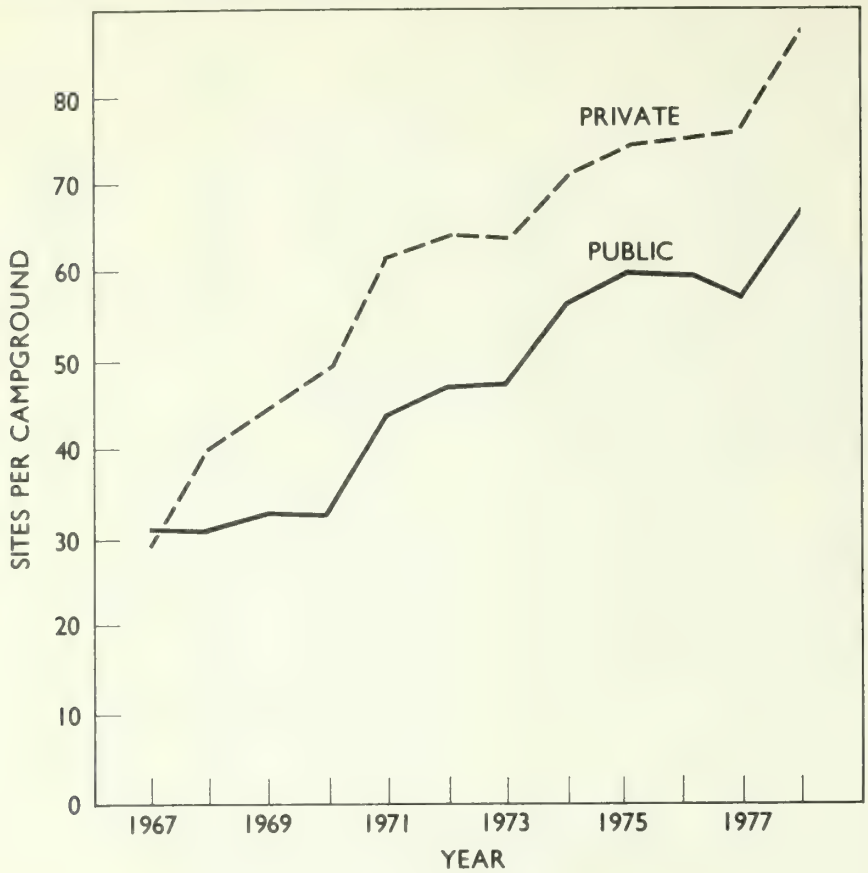
Woodall statistics indicate a trend toward larger campgrounds (Figure 6). In 1978 listed private campgrounds averaged 88 sites—a 214 percent increase over the 1967 average of 28 sites. In a study of private campgrounds in the Northeastern states, the NEM-42 Technical Research Committee found clear evidence that campgrounds with fewer than 50 sites were much less likely to be successful than larger areas (Bevins et al. 1974). Increase in the size of individual areas is additional evidence that the campground industry is maturing.

Public campgrounds have also shown a general trend toward increased size. The average size of public campgrounds has more than doubled, from 31 sites in 1967 to 67 in 1978.

### Onsite conveniences

Woodall statistics indicate that in 1977 three-fourths or more of all individual private

Figure 6.—Average number of campsites per campground listed by Woodall Publishing Co., 1967-1978.




campsites had electricity and water (Table 21). Less than one-fourth of the public sites had electricity, and only one-tenth had water at each individual site.

The percentage of total public campgrounds with onsite hookups remained the same from 1976 to 1977. Generally, public campgrounds stress the aesthetic amenities of the natural environment and place little emphasis on convenience facilities at each individual site. The provision of onsite conveniences has unofficially been considered to be a responsibility of the private sector. Between 1976 and 1977, the private sector made only modest increases in the number of onsite conveniences.

The latest Woodall figures show that in 1978, 84 percent of private campsites listed by Woodall had at least one hookup. This percentage is substantially higher than the 24 percent of public campsites having at least one hookup.

**Table 21.—Percentage of campsites with onsite conveniences in public and private campgrounds, 1976 and 1977**

| Type of convenience | Public sector | | Private sector | |
|---|---|---|---|---|
| | 1976 | 1977 | 1976 | 1977 |
| Electricity | 23 | 23 | 81 | 82 |
| Water | 10 | 10 | 73 | 75 |
| Sewer | 3 | 3 | 37 | 39 |

Source: Woodall, 1978.

### Camping fees

Camping fees are the basis for recovery of the costs of land acquisition, facility development, and daily operations. Although most private campground owners depend entirely

on site rentals and profit centers to meet these expenses, the public sector frequently recovers such costs through a combination of fees and tax dollars.

*Basic fees at public and private areas—Northeast.* Analysis of Rand McNally northeastern campground listings indicates that daily fees charged for trailer sites at privately operated camping areas were 43 percent higher than fees charged for similar sites at public campgrounds (Tables 22 and 23). The basic fee at private campgrounds averaged

**Table 22.—Public campsites fees in the Northeast, 1973 and 1977 (same campgrounds both years)**

| State | Tent sites | | | Trailer sites | | |
|---|---|---|---|---|---|---|
| | Average campsite fee[a] | | Number of campgrounds | Average campsite fee[a] | | Number of campgrounds |
| | 1973 | 1977 | | 1973 | 1977 | |
| Connecticut | $2.12 | $2.12 | 17 | $2.13 | $2.13 | 16 |
| Delaware | 3.00 | 4.00 | 3 | 3.00 | 4.00 | 3 |
| Maine | 2.70 | 3.02 | 23 | 3.09 | 3.50 | 16 |
| Maryland | 2.53 | 3.00 | 20 | 2.53 | 3.00 | 20 |
| Massachusetts | 3.04 | 3.78 | 23 | 3.04 | 3.78 | 23 |
| New Hampshire | 2.05 | 2.79 | 29 | 2.07 | 2.87 | 23 |
| New Jersey | 2.11 | 4.17 | 18 | 2.18 | 4.25 | 17 |
| New York | 2.50 | 2.98 | 100 | 2.57 | 3.07 | 91 |
| Pennsylvania | 2.31 | 2.53 | 54 | 2.31 | 2.53 | 54 |
| Rhode Island | 2.00 | 2.75 | 4 | 2.25 | 3.00 | 4 |
| Vermont | 3.20 | 3.61 | 41 | 3.26 | 3.71 | 36 |
| West Virginia | 1.93 | 2.51 | 36 | 2.09 | 2.74 | 35 |
| Regional average | 2.46 | 3.11 | 31 | 2.54 | 3.22 | 28 |

Source: Rand McNally 1973, 1977.
[a]Campsite fees represent averages weighted by number of campgrounds.

**Table 23.—Private campsite fees in the Northeast, 1973 and 1977 (same campgrounds both years)**

| State | Tent sites | | | Trailer sites | | |
|---|---|---|---|---|---|---|
| | Average campsite fee[a] | | Number of campgrounds | Average campsite fee[a] | | Number of campgrounds |
| | 1973 | 1977 | | 1973 | 1977 | |
| Connecticut | $3.45 | $4.55 | 32 | $3.54 | $4.70 | 36 |
| Delaware | 3.36 | 4.64 | 11 | 3.65 | 5.08 | 13 |
| Maine | 3.40 | 4.29 | 168 | 3.61 | 4.72 | 171 |
| Maryland | 3.32 | 4.36 | 37 | 3.41 | 4.65 | 37 |
| Massachusetts | 3.55 | 4.57 | 76 | 3.71 | 4.95 | 79 |
| New Hampshire | 3.30 | 4.27 | 128 | 3.50 | 4.62 | 136 |
| New Jersey | 3.57 | 4.98 | 90 | 3.75 | 5.25 | 95 |
| New York | 3.09 | 4.01 | 295 | 3.27 | 4.27 | 315 |
| Pennsylvania | 2.98 | 3.95 | 253 | 3.05 | 4.13 | 266 |
| Rhode Island | 3.30 | 3.46 | 10 | 4.45 | 4.86 | 14 |
| Vermont | 3.13 | 3.84 | 67 | 3.28 | 4.09 | 69 |
| West Virginia | 2.79 | 3.59 | 27 | 3.16 | 3.92 | 27 |
| Regional average | 3.27 | 4.21 | 100 | 3.53 | 4.60 | 105 |

Source: Rand McNally 1973, 1977.
[a]Campsite fees represent averages weighted by number of campgrounds.

$4.60 in 1977, compared with $3.22 at public campgrounds.

*Fee changes between 1973 and 1977—Northeast.* Further analysis of Rand McNally northeastern states campground listings indicates that while both public and private areas raised fees between 1973 and 1977, the increase was slightly greater at private areas —30 percent as compared with 27 percent. Disaggregation of the data shows a wide variation between states in price increases in the public sector during this 5-year period (Figure 7). Looking at the extremes, there was no price increase at Connecticut's public campgrounds, whereas there was a 95 percent increase at New Jersey's. Private campground fees in Vermont increased only 25 percent, while private campgrounds in New Jersey raised prices 40 percent.

*Willingness to pay.* The public's attitude toward fees was the subject of a national household survey conducted for BOR in 1975. This survey assessed public willingness to pay for several outdoor recreation activities, including camping (Economics Research Associates 1976). Respondents participating in this survey generally felt that fees at public areas should be lower than those charged at private recreation areas (Figure 8).

When asked to compare the fee paid on their last camping trip with the fee they would be willing to pay, campers "voted" for a larger increase at developed public campgrounds than at private campgrounds (Figure 9). Survey findings show that campers generally support fee increases at public areas of approximately $0.70 for tent camping and $0.66 for RV camping. Acceptable increases in camping fees at private campgrounds were approximately half those for public campgrounds—probably because current fees at private campgrounds are higher than those at public areas.

Another indication that campers may be willing to pay higher public camping fees is

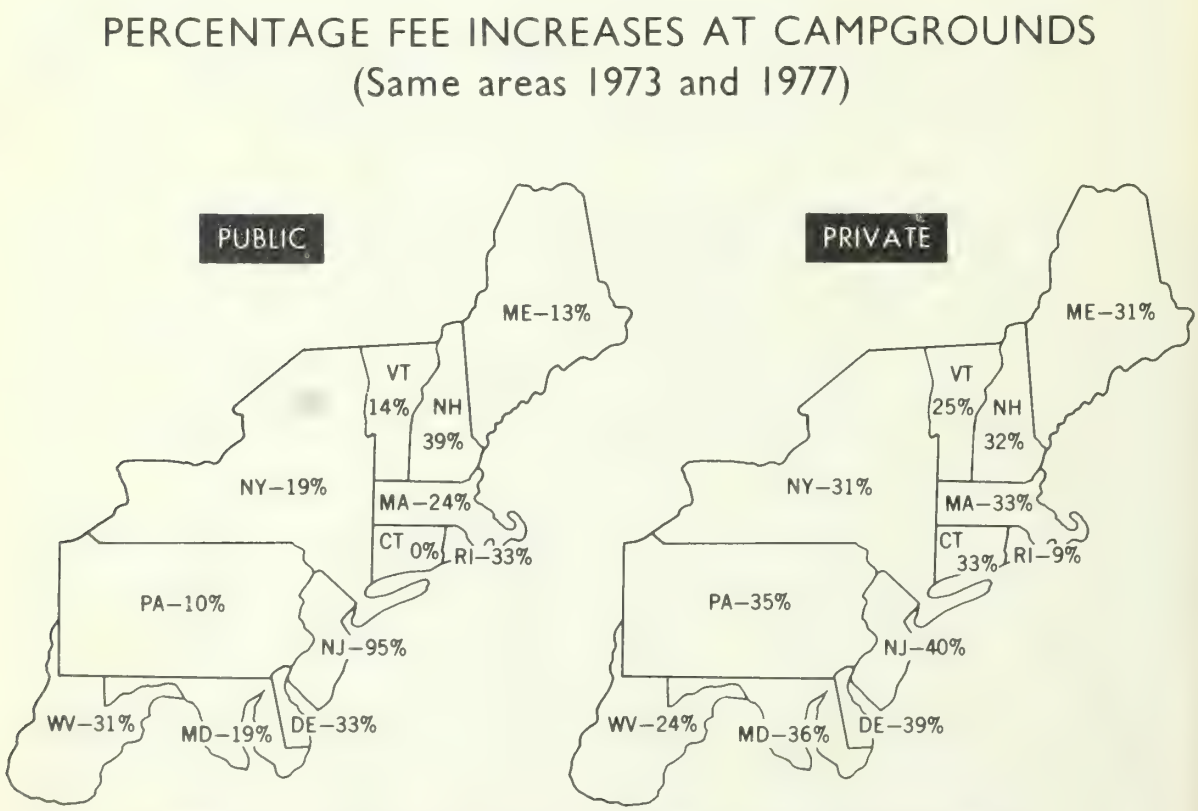



**Figure 7.—Percentage change in campsite fees at campgrounds in the Northeast listed by Rand McNally, between 1973 and 1977.**

Bevins, Malcolm I., Wilbur F. LaPage, and Daniel P. Wilcox.
1979. **The campground industry—recent national trends.** Northeast. For. Exp. Stn., Broomall, Pa.
41 p., illus. (U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-53)

A comprehensive review of recent trends indicates that the number of United States campers is increasing by 1 or 2 percent annually. The supply of public and private campsites has stabilized at approximately 1 million. The small minimal-facility private campground is being replaced by larger convenience-oriented resort campgrounds. Industry leaders looking toward 1985 foresee: (1) a slower rate of new campground development, (2) more campgrounds closer to population centers, (3) more full-season campsite rentals, (4) more on-site RV rentals, (5) a slight decrease in Federal campsites, and (6) more public agency use of concession management.

**Keywords:**
Campgrounds, recreation, leisure, tourism, trends, marketing, pricing, economics

Bevins, Malcolm I., Wilbur F. LaPage, and Daniel P. Wilcox.
1979. **The campground industry—recent national trends.** Northeast. For. Exp. Stn., Broomall, Pa.
41 p., illus. (U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-53)

A comprehensive review of recent trends indicates that the number of United States campers is increasing by 1 or 2 percent annually. The supply of public and private campsites has stabilized at approximately 1 million. The small minimal-facility private campground is being replaced by larger convenience-oriented resort campgrounds. Industry leaders looking toward 1985 foresee: (1) a slower rate of new campground development, (2) more campgrounds closer to population centers, (3) more full-season campsite rentals, (4) more on-site RV rentals, (5) a slight decrease in Federal campsites, and (6) more public agency use of concession management.

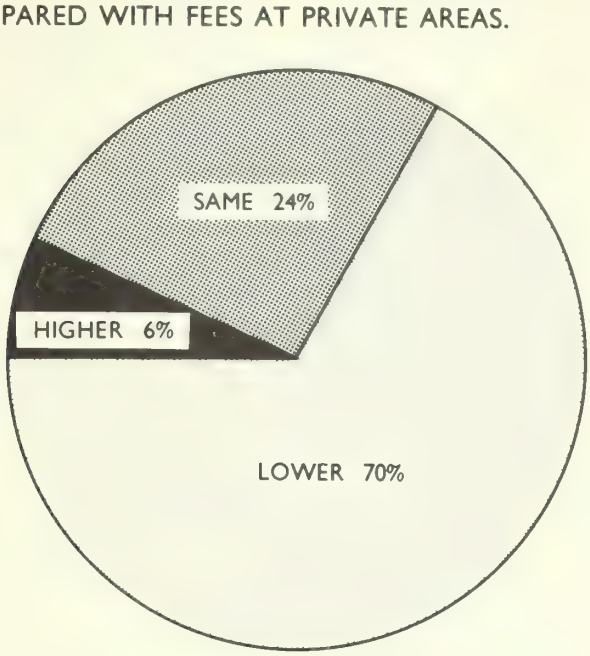
**Keywords:**
Campgrounds, recreation, leisure, tourism, trends, marketing, pricing, economics

Bevins, Malcolm I., Wilbur F. LaPage, and Daniel P. Wilcox.
1979. **The campground industry—recent national trends.** Northeast. For. Exp. Stn., Broomall, Pa.
41 p., illus. (U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-53)

A comprehensive review of recent trends indicates that the number of United States campers is increasing by 1 or 2 percent annually. The supply of public and private campsites has stabilized at approximately 1 million. The small minimal-facility private campground is being replaced by larger convenience-oriented resort campgrounds. Industry leaders looking toward 1985 foresee: (1) a slower rate of new campground development, (2) more campgrounds closer to population centers, (3) more full-season campsite rentals, (4) more on-site RV rentals, (5) a slight decrease in Federal campsites, and (6) more public agency use of concession management.

**Keywords:**
Campgrounds, recreation, leisure, tourism, trends, marketing, pricing, economics

**Figure 8.—Responses to the statement "Fees at public areas should be (higher) (the same) (lower) compared to fees at private areas." Source: Economics Research Associates 1976.**



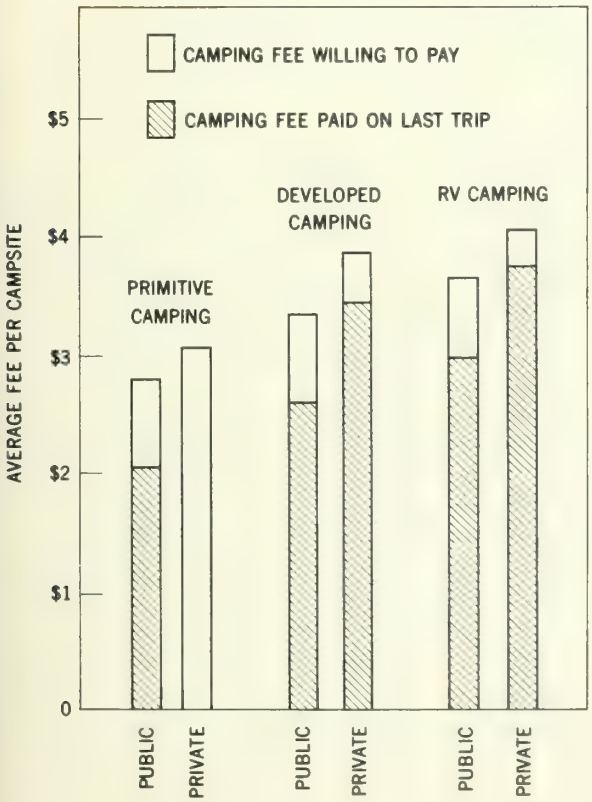




**Figure 9.—Public willingness to pay for camping at public and private areas, 1975. Source: Economics Research Associates 1976.**

noted in a 1975 Delaware state park camper survey (Brokaw and Cole 1977). Campers participating in this study indicated a willingness to pay 15 percent more than the actual fees being charged in 1975.

### Campground development costs in 1977

In 1971 the NEM-42 Technical Research Committee found that the unit cost of campground development decreases somewhat in proportion to total campground size (Bevins et al. 1974:14). The 1971 NEM-42 campground development costs were projected to 1977 levels using the U.S. Department of Commerce's Construction Cost Index. These projected figures indicate that in 1977 small-scale campgrounds (31 sites) would have development costs of $3,000 per campsite (see

Table 24). Large campgrounds (263 sites) would have unit development costs of one-half this amount ($1,500 per site). The average unit development cost for all sizes of campgrounds in 1977 was estimated to be $2,100 per unit.

Generally, the most important factor in determining capital requirements for campground development is level of development. One measure is the number of RV service hookups provided at each campsite. Statistics compiled by the Woodall Publishing Company show that the cost of developing campsites with three-way hookups (electricity, water, and sewer) is almost triple the cost for sites with no hookups (Table 24). The estimated cost for all types of sites, according to Woodall, is $1,800 per site.

In 1977 Oertle compared campground development costs for the six major franchise campground chains (Table 24). Costs for franchise campgrounds ranged from $1,800 to $3,000 per campsite, with an average of $2,300.

The U.S. Soil Conservation Service (SCS) has also prepared capital cost estimates for campground development. Their data indicate that in 1977 persons planning to construct developed camping areas should expect to pay between $2,500 and $4,500 per campsite (Table 24).

**Table 24.—Estimated campground development costs per campsite, 1977[a]**

| Source of estimate | Type of campground | Estimated cost per campsite |
|---|---|---|
| Bevins et al. 1974:14[b] | Average number of sites per campground | |
| | 31 | $3,000 |
| | 72 | 2,200 |
| | 108 | 2,000 |
| | 146 | 1,800 |
| | 263 | 1,500 |
| | (Unweighted average) | ($2,100) |
| Fuller 1972:2-3[b] | Onsite conveniences | |
| | 3 hookups (electricity, water, sewer) | $2,600 |
| | 2 hookups (electricity, water) | 2,100 |
| | 1 hookup (electricity) | 1,700 |
| | No hookups | 900 |
| | (Unweighted average) | ($1,800) |
| Oertle 1977:38 | Franchise campgrounds | |
| | Ramada | $3,000 |
| | Trav-L-Parks | 2,500 |
| | Jellystone | 2,400 |
| | Kamp Dakota | 2,000 |
| | United Safari | 2,000 |
| | Kampgrounds of America | 1,800 |
| | (Unweighted average) | ($2,300) |
| U.S. Soil Conservation Service 1977:8-11 | All types | $2,500–$4,500 |

[a]Estimated costs per campsite include all land, structures, and amenities associated with campground development.

[b]The 1971 campsite development costs published in this report have been updated to reflect estimated 1977 costs by using the Construction Cost Index published annually by the U.S. Department of Commerce in Survey of Current Business.

## THE CAMPING INDUSTRY—PUBLIC-PRIVATE INTERFACE

In the early years, campground development in the United States was strictly a public sector undertaking. As the desire to participate in outdoor recreation increased, the public sector responded admirably by providing spacious, rustic, wooded sites where the outdoors might be enjoyed.

Charging fees sufficient to cover development and operating costs in publicly operated areas was not a prime concern in the early years. As recently as 1960, fees in Federal or state parks were in the $1 to $2 range (Bond et al. 1973).

In the early 1960's, the advent of the recreational vehicle signaled a new era in campground development. More campers started looking for conveniences and were less concerned with spaciousness. Private enterprise saw a business opportunity in providing convenience camping and assumed a major role in developing this newly created market.

Generally, public campground administrators agree that convenience sites and intensive development should be left to the private sector. Most administrators feel a greater obligation to develop *parks* than campgrounds (Bond et al. 1973:35).

However, public campground administrators now find themselves in a dilemma. Many recreational vehicles have been sold since the early 1960's, and few have been discarded. On the one hand, some of these RV owners prefer the spacious wooded sites in National Parks and Forests to the smaller and less wooded site typical of privately operated campgrounds. However, in addition to a spacious site, they seek the convenience of onsite electricity and water. On the other hand, public administrators feel pressures from private campground operators and backcountry campers seeking a de-emphasis of convenience-type facilities and a return to the relatively primitive accommodations at public areas (Bond et al. 1973:36).

### The identified role and problems of the private sector

Since the early 1960's, several commissions and task forces have been organized to define the private sector's role in supplying outdoor recreation opportunities and the problems in fulfilling this role.

*The U.S. Outdoor Recreation Resources Review Commission (ORRRC)—1962.* The ORRR Commission prepared the first major report to specifically identify the proper role of the private sector. In order to implement a national outdoor recreation policy "which would make accessible to all American people the [needed] quantity and quality of outdoor recreation," it is necessary that ". . . individual initiative and private enterprise should continue to be the most important force in outdoor recreation . . . [government] should stimulate desirable commercial development . . . where demand is sufficient to return a profit (U.S. Outdoor Recreation Resources Review Commission 1962:6).

The ORRR Commission concluded that:

> Camping is becoming a significant part of vacation travel in the United States. For the most part, campers have depended upon Federal and State Parks and Forests . . . Yet, it is probable that farm and forest lands could be developed and managed so as to provide camping opportunities in areas where demand exceeds the capacity of public facilities, (U.S. Outdoor Recreation Resources Review Commission 1962: 161).

*Federal Work Group H Report—1972.* In 1972 a team of 20 Federal experts (Group H) was organized by BOR to identify problems and alternatives relative to the private sector's involvement in outdoor recreation. In general, the Work Group agreed:

> The public sector should encourage and assist the private sector in the provision of outdoor recreation opportunities, programs, and services . . . existing problems that limit the effectiveness of the private sector in taking a greater role in the provision of recreation opportunities need to be identified and solved.[3]

[3]Federal Work Group H. 1972. A report on private sector contribution to recreation. Unpublished preliminary report.

The Work Group identified several problems caused directly by public campground development and operational policy decisions:

1) Economic success of private recreation enterprises is sometimes jeopardized by low-priced competition from public facilities.
2) The interstate sign program greatly favors public facilities.
3) The public sector's promotional and information programs tend to overshadow the private sector's efforts (See footnote 3, p. 23.)

Several alternative solutions to these problems were identified. Two of these solutions related to a needed change in public policy:

1) Public policy should increase complementary and reduce competitive relationships between the private and the public sectors.
2) The public sector should not provide services that can be more efficiently provided by the private sector.

*BOR Task Force V—1977.* Public Law 88-29 directs the Secretary of the Interior to formulate a national outdoor recreation plan that shall

> Identify critical outdoor recreation problems, recommend solutions, and recommend desirable actions to be taken at each level of government and by private interests.

The first "nationwide plan" was published in 1973. Although many issues were addressed, treatment of private-sector issues was, at best, sketchy. Recognizing that the PL 88-29 directive relating to private interests was not addressed in the 1973 plan, BOR took corrective action in the development of the 1978 Plan. In 1977 BOR organized a task force of university and Forest Service researchers with the express mission to:

> Develop a better understanding of the nature and capabilities of the private sector and to determine what role the federal government has in stimulating and assisting the private sector in providing outdoor recreation opportunity.[4]

In assessing the public-private interface, Dr. Clare Gunn, a member of the Task Force, stated the situation well:

> Some attention to the symbiotic and synergistic relationship [between recreation-conservation-and tourism] is now necessary on the part of both government and private enterprise . . . both business and public agency inputs are equally essential in the overall phenomenon . . . It is the public—not anti-social and money mad entrepreneurs—that demands commercial services and products. (See footnote 4.)

In an effort to identify issues of greatest concern to the private sector, a joint meeting was staged in July 1977 between Task Force members and national leaders and representatives of the private recreation industry. Discussions of specific issues took place in a workshop environment. Participants in one of the workshops concluded:

> The public and private sectors can combine to provide the user with a complete recreation experience . . . however, public recreation developments can be very damaging to the private sector when they provide unfair competition.[5]

A final report of Task Force V will be published by BOR as a resource document for the 1978 Nationwide Outdoor Recreation Plan.

*National Tourism Policy Study—1977.* On June 24, 1974 the U.S. Congress authorized the Senate Commerce Committee to conduct a National Tourism Policy Study (U.S. Senate Resolution 347). The results of this study, which contains extensive information from both public and private sectors of the travel and tourism industry, were published in April 1978 (U.S. Senate 1978).

In the course of this study, a series of seven meetings was held in Washington with representatives of 143 different recreation or tourism organizations. Three issues related to the U.S. camping industry emerged as most critical: (1) the need for research; (2) the need for coordinated federal and private tourism promotion; and (3) the need for raising low federal recreation fees (Table 25).

In assessing specific needs for Federal program changes, National Tourism Policy Study participants stated that:

[4]Honore, W. H., L. Askham, M. Bevins, K. Cordell, A. Epperson, R. Espeseth, C. Gunn, W. La Page, and D. Schink. 1977. The Federal role in the private sector of outdoor recreation. Preliminary draft. U.S. Bureau of Outdoor Recreation, Washington, D.C.

[5]Financial and Technical Assistance Workshop (sponsored by U.S. Bureau of Outdoor Recreation). July 1977. Unpublished proceedings. Washington, D.C.

Tourism facilities owned and operated by the Federal Government should be managed in ways that avoid unfair competition with private sector facilities.

Regulatory restrictions should be equally applied to public sector and private sector facilities. Public sector facilities should also be required to make payments in lieu of tax in order to equalize the tax burden carried by public and private sector facilities. Federal campgrounds, for example, frequently are required to meet less strict development requirements and do not have the tax burden carried by privately owned campgrounds.

User charges for Federal recreational and tourism facilities should be increased where these are clearly shown to be engendering unfair competition with private sector facilities of equal quality and design on adjacent or nearby property.

Public investment in parklands and recreational lands often has a stimulatory effect on private sector investment in the same area. However, greater emphasis should be put on maintaining public parklands through user charges, rather than through general tax revenues where a subsidy of public sector facilities is causing unfair competition with the private sector (U.S. Senate 1977:53).

### Public development impact assessment

The Heritage Conservation and Recreation Service (HCRS, formerly BOR) has taken the lead in attempting to improve relations with the private sector. It has recognized that if the needs of the camping public are to be met, a complementary development policy must be established between public and private sectors. HCRS now requires a formal site-by-site impact analysis (financial impact of public recreational development on private enterprise) before Federal Land and Water Conservation funds can be used by any public agency (U.S. Bureau of Outdoor Recreation 1973).

To properly prepare an impact assessment, basic information is needed on current occupancy rates and levels of satisfaction at existing public and private campgrounds. Such information does not exist, at least not in readily usable form for a broad geographic area.

The private campground sector is taking the initiative to fill this data void through the development of two national data series—one measuring campground occupancy and the other, camper satisfaction.

*National Campground Occupancy Index.* On November 14, 1977, the Board of Directors of the National Campground Owners Association (NCOA) voted to coordinate a reporting process of occupancy levels with a nationwide sample of private campgrounds. In 1978 selected campgrounds reported their occupancy on a weekly basis (see Appendix, p. 36). From these records a "National Campground Occupancy Index" was compiled and published weekly throughout the season for four identified regions of the United States (Northeast, North Central, South, and West). The devel-

**Table 25.—Importance of public/private relationship policy issues, as rated by national panel of private-sector tourism/recreation representatives, 1977 (in percent of panel members assigning each rating)**

| Policy | Rating | | | | |
|---|---|---|---|---|---|
| | Important | Somewhat important | Not important | No opinion | Total |
| Improve coordination with private sector to develop useful tourism *research* data | 63 | 30 | 5 | 2 | 100 |
| Coordinate Federal and private sector site-specific *tourism promotional programs* to expand local tourism markets rather than compete for individual market shares | 58 | 17 | 6 | 19 | 100 |
| Reduce negative impacts of *low federal recreation fees* on nearby private sector operations | 33 | 26 | 25 | 16 | 100 |

Source: U.S. Senate 1977.

opment and maintenance of a nationwide campground occupancy monitoring system is both feasible and highly desirable, based on the quality of data reported and the industry-wide enthusiasm for the plan. A final selection of 94 campgrounds was made from the 117 volunteers contacted in the Spring of 1978, providing a sample that appeared to be representative of the nation's better-managed campgrounds. Initial selections were made from owners attending state association meetings and from national directory listings. Unrepresentative campgrounds, such as those having more than 50 percent of their capacities rented on a season-long basis, were eliminated. During the 14-week test period, the average response from the sample of campgrounds was 85 percent; the highest response (93 percent) occurred in the first week of July. This level of response, if it can be sustained, is more than adequate to provide a reliable data reporting system. (A minimum of 75 percent was the target.)

Just as the high rate of response confirms the feasibility of maintaining a monitoring system, the numerous requests received for detailed information and the voluntary financial sponsorship by the campground publishing industry attest to the need for this type of data.

The adequacy of the occupancy monitoring data can only be inferred, since there are no standards with which to compare our findings. In general, the occupancy figures appear to be reasonable for each region, with the possible exception of the West, which averaged the highest season-long level of attendance (Table 26).

The regional differences in season-long occupancy trends reflect expected differences in regional camping behavior (Figures 10 to 14). For example, the spread between weekday and weekend occupancy is narrowest in the West, where greater travel distances should produce a lower proportion of weekend camping. Similarly, the August slump in camping activity, which is universal, is least pronounced in the West. The sustained, season-long increase in northeastern campground occupancy probably reflects the generally easier access, comparative abundance, and variety of tourist attractions that characterize this smallest of the four regions.

**Table 26.—Percent occupancy at sampled campgrounds, Memorial Day to Labor Day, 1978**

| Region | Average weekday occupancy | Weekday low | Weekday high | Average weekend occupancy | Weekend low | Weekend high | Total occupancy | Long-term rentals |
|---|---|---|---|---|---|---|---|---|
| Northeast | 58 | 36 | 72 | 77 | 48 | 96 | 63 | 23 |
| North Central | 43 | 35 | 54 | 61 | 44 | 80 | 49 | 9 |
| South | 49 | 34 | 64 | 60 | 46 | 83 | 52 | 11 |
| West | 67 | 47 | 77 | 71 | 51 | 80 | 68 | 4 |
| Total United States | 54 | 39 | 66 | 68 | 47 | 85 | 58 | 14 |

Figure 10.—Seasonal trend in campground occupancy for Northeastern Region, May 29 to September 3, 1978.

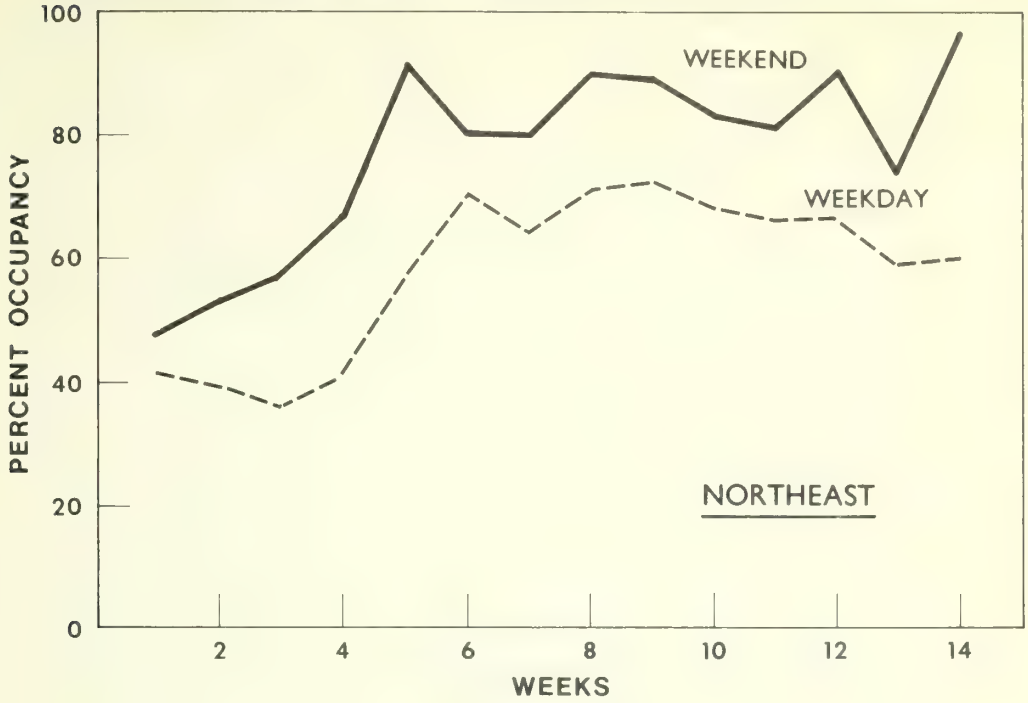



Figure 11.—Seasonal trend in campground occupancy for North-Central Region, May 29 to September 3, 1978.

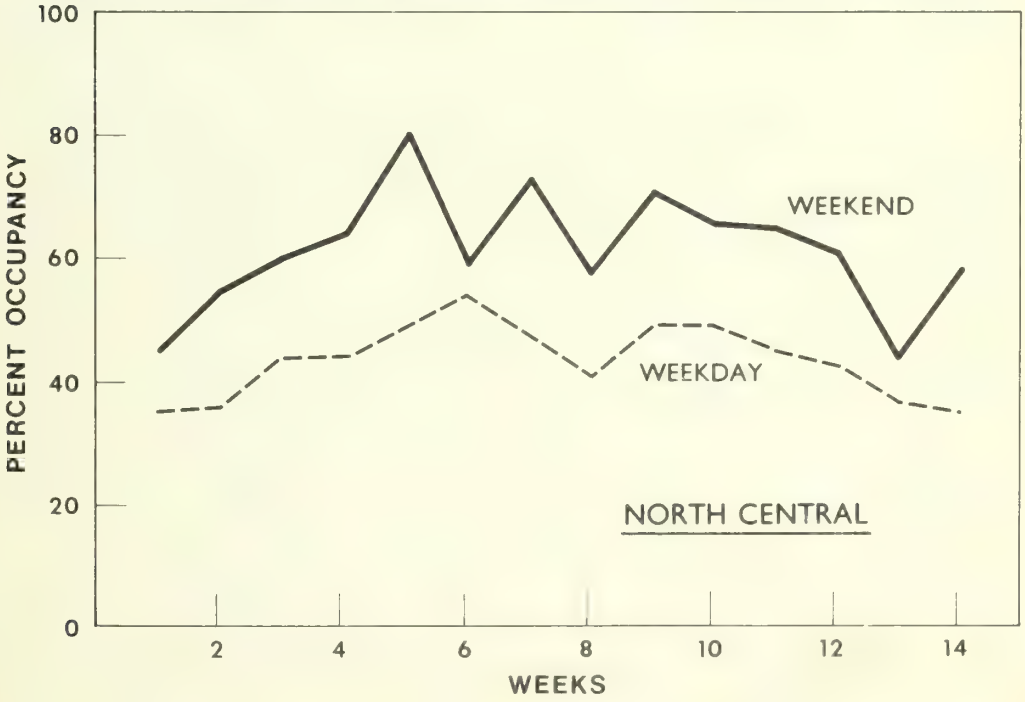


Figure 12.—Seasonal trend in campground occupancy for Southern Region, May 29 to September 3, 1978.

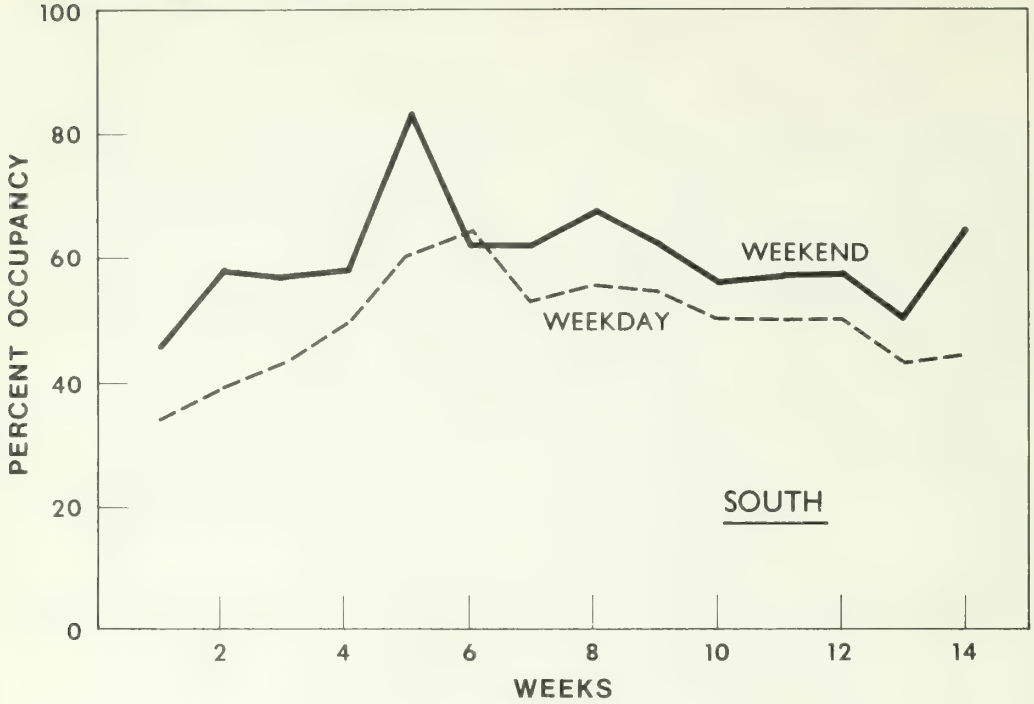



Figure 13.—Seasonal trend in campground occupancy for Western Region, May 29 to September 3, 1978.

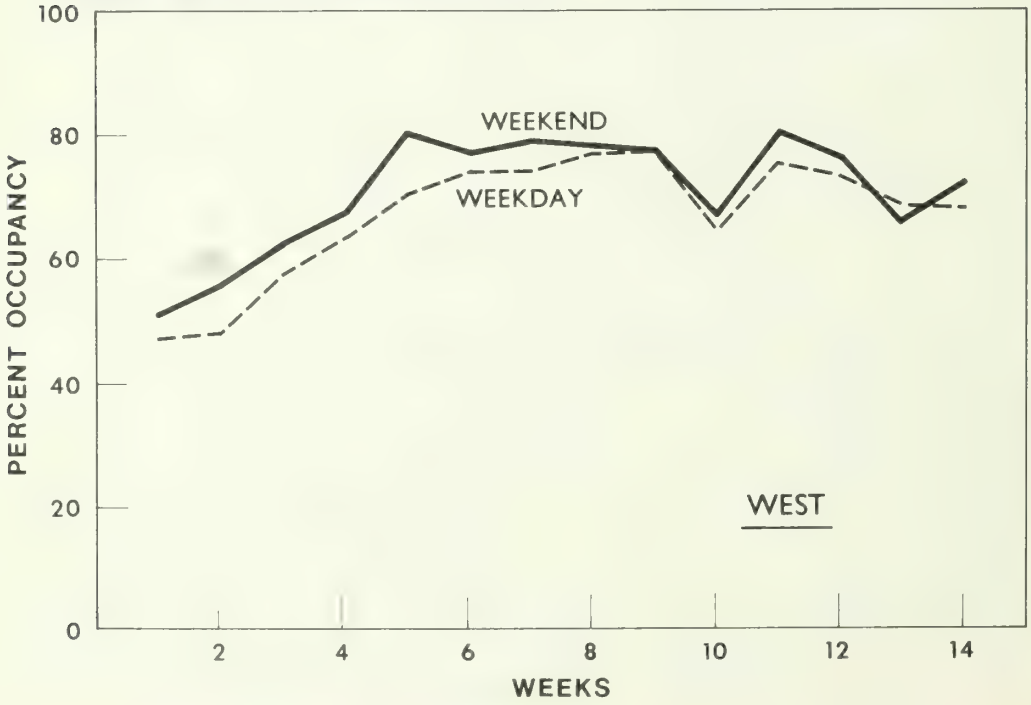
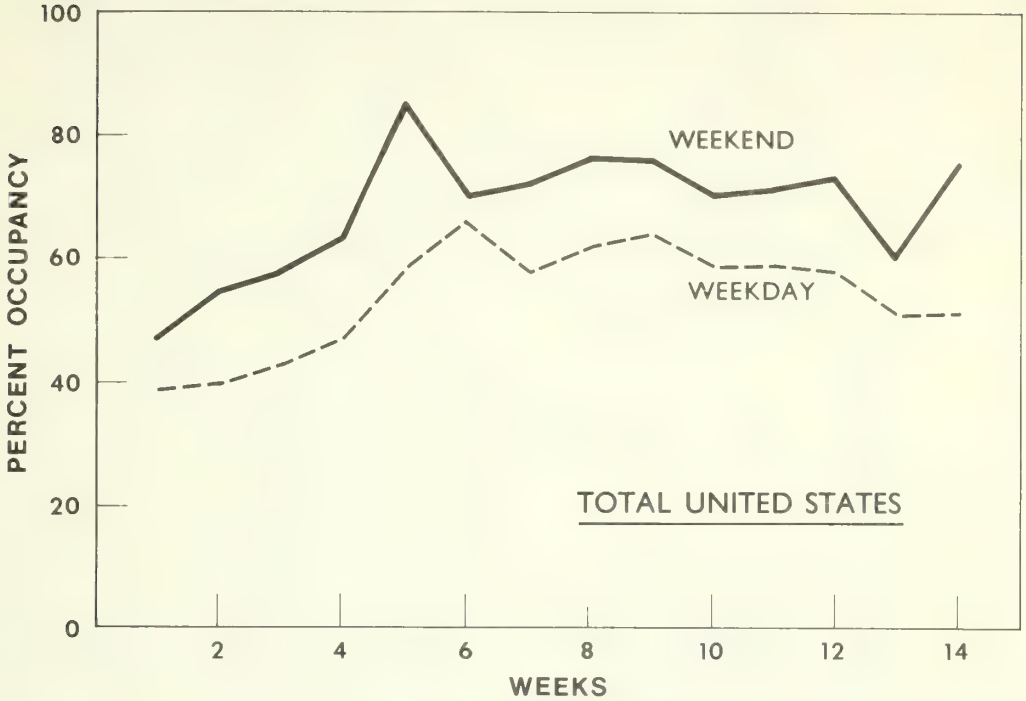


Figure 14.—Seasonal trend in campground occupancy for all regions, May 29 to September 3, 1978.




The data generated by the occupancy index network of campgrounds for national and regional monitoring purposes appear adequate. However, this information is currently useless for statewide purposes because of the small sample size. Five states were not represented in the Index at all, and 16 others had only one reporting campground. Only 14 states had more than two reporting campgrounds. Because statewide data are critical to the industry, and because such data can be aggregated to produce both regional and national statistics, it seems advisable to expand the network of reporting campgrounds. This published index fills a void and should be of immeasurable value in the development of impact statements by the public sector.

*National Camper Satisfaction Index.* The National Campground Owners Association similarly endorsed the development of the "National Camper Satisfaction Index." The national index includes 14 elements, several of which will be most useful to public resource managers in determining whether or not camper needs are being met by the private sector. In 1978 campers visiting any one of a nationwide network of campgrounds were asked to evaluate their camping experience (see Appendix, p. 37). Camper evaluations were summarized both nationally and regionally for the four areas identified previously. The data generated by the satisfaction monitor showed that commercial campgrounds were fully as satisfying to campers as the two state park campground systems used for comparison purposes (Table 27). The report-card evaluation approach works very well and produces high-quality data, with many campers going beyond the assigned grading system to indicate their true feelings (e.g., A++ or C−). There is an unexplained difference in response rates, however, between public and private campgrounds. The former frequently return upward of 50 percent of the report cards, while the best response rate from any of the commercial campgrounds has been only 36 percent.

Although we promptly reported the satis-

**Table 27.—Ratings on the "Report Card" camper satisfaction survey conducted in 1978 at 122 public and private campgrounds**

| Ratings on: | State Park system A | State Park system B | Total public | Commercial campgrounds | Total public and commercial |
|---|---|---|---|---|---|
| First impression | 6.2 | 7.0 | 6.9 | 6.5 | 6.5 |
| Cleanliness of campsites | 5.9 | 7.3 | 7.0 | 7.0 | 7.0 |
| Cleanliness of restrooms | 3.6 | 6.6 | 6.0 | 6.4 | 6.3 |
| Privacy of campsites | 5.9 | 6.6 | 6.4 | 5.8 | 6.0 |
| Good size of campsites | 6.8 | 7.2 | 7.1 | 6.3 | 6.4 |
| Good choice of campsites | 5.4 | 6.8 | 6.5 | 6.3 | 6.3 |
| Availability of firewood | 5.2 | 5.8 | 5.7 | 5.9 | 5.8 |
| Availability of supplies | 4.8 | 5.5 | 5.3 | 6.3 | 6.1 |
| Recreation opportunities | 5.7 | 6.0 | 5.9 | 6.3 | 6.2 |
| Ease of check-in (speed) | 5.8 | 7.1 | 6.8 | 7.0 | 6.9 |
| Safety and security | 5.7 | 7.0 | 6.8 | 6.7 | 6.7 |
| Good rules/regulations | 5.8 | 7.0 | 6.8 | 6.7 | 6.7 |
| Helpfulness of employees | 6.6 | 7.3 | 7.1 | 7.1 | 7.1 |
| Recommendation of campground | 6.3 | 7.3 | 7.1 | 6.8 | 6.9 |
| Overall voting | 5.7 | 6.7 | 6.5 | 6.5 | 6.5 |
| Number of respondents | 157 | 617 | 774 | 3,045 | 3,819 |
| Number of campgrounds | 4 | 11 | 15 | 107 | 122 |

Key
8 A Excellent
6 B Better than average
4 C Average
2 D Below average
0 E Poor

faction results to every participant, it is obvious that this type of data should be collected on a local basis and on a vastly larger scale than in this simple monitoring project. It therefore seems appropriate for NCOA to encourage individual campgrounds and state associations to adopt and use such a program, rather than to continue to monitor satisfaction on such a limited basis.

## CAMPING IN 1985

To gain a perspective on camping in the future, an opinion survey of camping industry leaders was undertaken. During the Fall of 1977, 12 informed representatives from the camping industry were asked to respond to a set of questions relating to their impressions of what camping would be like in 1985. Camping industry leaders participating in this survey included a balanced representation from public and private sectors, organized user groups, publishers, and consultants. Results of this survey are summarized below, and response frequencies for all questions appear in the Appendix (p. 38). The following camping patterns were seen as emerging between 1977 and 1985:

1) The total number of campers will increase.
2) The percentage of all campers who are retirees will increase.
3) Future campers will seek more convenience and a greater choice of recreational activity (Table 28).
4) Interest in swimming will be strong, and a swimming pool will be favored over a natural body of water.
5) Camping vacations will be longer; however, fewer campgrounds will be visited on each trip.
6) Camping at privately operated areas and in publicly managed backcountry will increase, whereas the level of camping in publicly developed areas will remain stable.

Evaluating supply, respondents foresaw the following situation in 1985:

1) An increase in the number of developed sites in both public and private sectors. (However, one-fourth of the respondents predicted a decrease in National Forest sites, and one-third predicted a decrease in National Park sites.)
2) Daily camping fees in 1985 at private areas with a swimming pool and two-way hookup (electricity and water) will range from $10 to $15, averaging about $12. Fees at public areas with similar offerings will average $9 per day.
3) Midsummer occupancy rates at campgrounds in:
   —National Parks will average 96 percent.
   —National Forests will average 82 percent.
   —Private franchise areas will average 83 percent.

**Table 28.—Number of respondents who predicted certain characteristics of campers in 1985; survey of 12 leaders in the camping industry, 1977**

| Camper characteristic | Demand for facility or program will | | |
|---|---|---|---|
| | Increase | Remain the same | Decrease |
| Want convenience and service | 7 | 5 | 0 |
| Want unorganized recreation at the campground | 7 | 4 | 1 |
| Use some type of RV | 7 | 3 | 2 |
| Want swimming pool | 6 | 6 | 0 |
| Want organized recreation at the campground | 5 | 6 | 1 |
| Want natural water swimming | 4 | 3 | 5 |
| Want an environmental education program | 2 | 8 | 2 |

—Private nonfranchised areas will average 76 percent.

Camping industry leaders expect the following campground management policies to be implemented by 1985:

A. *Public campground policies to expect in 1985:*
   1) Slower rate of *new* campground development, with continued expansion of *existing* campgrounds at the current rate.
   2) Construction of campgrounds closer to population centers.
   3) Increased separation of RV sites from tent sites within the same campground.
   4) Greater reliance on privately operated concessionaire campgrounds.
   5) More environmental education programs at campgrounds.

B. *Private campground policies to expect in 1985:*
   1) Development of new campgrounds at a *slower rate* and expansion of existing campgrounds at the same or at an increased rate.
   2) More full-season campsite rentals.
   3) More onsite RV rentals.
   4) Increased condominium campsite sales.
   5) Greater provision of organized social and recreation programs.
   6) Off-season equipment storage at the campground.

## SUMMARY OF MAJOR FINDINGS

1) Demand for developed camping is increasing at a rate slightly greater than that of general population growth. The total number of campers appears to be increasing by about 1 to 2 percent per year.

2) The national supply of developed public campsites has been relatively stable over the past 5 years. Although the U.S. Army Corps of Engineers has recently developed more camping areas, the U.S. Forest Service and the U.S. National Park Service have made no significant campsite additions to their respective systems.

3) The rate of growth in the private campground sector has decreased considerably compared with growth in the 1960's. However, private-sector management and marketing techniques have become more sophisticated. Small, minimal facility campgrounds are being replaced by larger convenience-oriented areas.

4) Private campground owners continue to feel that the public sector is competing unfairly in furnishing developed camping areas. Low public camping fees and provision of convenience facilities are cited as contributing factors.

5) Fee increases at public campgrounds continue to be lower than those at privately operated campgrounds.

6) Campers have expressed a willingness to pay higher fees at both public and private campgrounds.

7) The cost of private campground development averaged more than $2,000 per site in 1977—just under $250,000 for a 100-site campground.

8) Recreational vehicles continue to be the most popular camping shelter at developed campgrounds. RV campers tend to participate more frequently than tent campers.

9) At the time this study was conducted, most campers did not appear to be affected by the energy situation. Despite fuel price increases, campers had not reduced camping-related travel.

10) There is a pressing need to improve coordination among the public and private camping suppliers if the diverse needs of the camping public are to be met.

## LITERATURE CITED


A. C. Nielsen Company.
1976. **Nielsen releases additional details of sports participation study.** A. C. Nielsen News, Northbrook, Ill.

American Forest Institute.
1977. **The public's participation in outdoor activities and attitudes toward National Wilderness areas.** Washington, D.C.

Bevins, Malcolm I., T. L. Brown, G. L. Cole, et al.
1974. **Analysis of the campground market in the Northeast. Report II: Privately owned areas.** Vt. Agric. Exp. Stn. Bull. 679.

Bond, Robert S., M. I. Bevins, T. L. Brown, et al. (NEM-42 Research Committee).
1973. **Analysis of the campground market in the Northeast—public policy.** Mass. Agric. Exp. Stn. Bull. 601.

Brokaw, Marion J., and Gerald L. Cole.
1977. **An economic analysis of camper equipment preferences, facilities, and fees in relation to income.** Delaware Agric. Exp. Stn. Bull. 422.

Economics Research Associates.
1976. **Evaluation of public willingness to pay user charges for use of outdoor recreation areas and facilities.** [Prepared for the U.S. Bureau of Outdoor Recreation, Washington, D.C.]

Ferris, Abbott L., et al.
1962. **National recreation survey.** ORRRC study report 19. U.S. Gov. Print. Off., Washington, D.C., p. 31.

Fuller, Curtis G.
1972. **Toward development of a national RV/camping policy.** *In* Woodall's mobile home and park directory. Woodall Publishing Company, Highland Park, Ill., p. 2–3.

Kampgrounds of America.
1976. **1976 camper survey.** Billings, Mont.

Kottke, Marvin, W., Malcolm I. Bevins, Gerald L. Cole, et al. (NEM-42 Research Committee).
1975. **Analysis of the campground market in the Northeast. Report III: A perspective on the camping involvement cycle.** U.S. Dep. Agric. For. Serv. Res. Pap. NE-322.

LaPage, Wilbur F.
1973. **Growth potential of the family camping market.** U.S. Dep. Agric. For. Serv. Res. Pap. NE-252.

Los Angeles Times.
1977. **Recreational vehicle industry looks up.** [Reported in the Burlington (Vt.) Free Press, November 13, 1977, p. 9B.]

Marketing Handbooks, Inc.
1978. **Travel marketing yearbook.** Stamford, Conn.

North American Family Campers Association.
1977. **Editorial.** A hill of peanuts. Campfire Chatter, August 1977. Newburyport, Mass., p. 12.

Opinion Research Corporation.
1977. **1977 on-site recreation survey: preliminary tabulations.** Princeton, N.J. [Prepared for the U.S. Bureau of Outdoor Recreation.]

Oertle, V. Lee.
1977. **The franchise phenomenon.** *In* Woodall's trailer and RV travel. Woodall Publishing Company, Highland Park, Ill., p. 38.

Rand McNally and Company.
1973 and 1978. **Rand McNally campground and trailer park guide.** Chicago, Ill.

Recreation Vehicle Industry Association.
1976. **RVIA marketing report.** December 1976. Chantilly, Va.

Recreation Vehicle Industry Association.
1977. **RVIA facts and trands, 1976–1977.** Chantilly, Va.

Recreation Vehicle Industry Association.
1978. **RVIA marketing report.** July 1978. Chantilly, Va.

U.S. Army Corps of Engineers.
1975. **Recreation statistics.** Washington, D.C.

U.S. Army Corps of Engineers.
1976. **Preliminary RRMS report data, August 1976.** Washington, D.C.

U.S. Army Corps of Engineers.
1976 and 1977. **RRMS annual reports.** Washington, D.C.

U.S. Bureau of the Census.
1976. **Statistical abstract of the United States, 1976.** Washington, D.C., p. 396.

U.S. Bureau of Outdoor Recreation.
1973. **BOR recreation manual.** Grant-In-Aid Ser. Parts 640.3.1 and 660.2.21.

U.S. Bureau of Outdoor Recreation.
1973. **Outdoor recreation: a legacy for America.** U.S. Gov. Print. Off., Washington, D.C.

U.S. Forest Service.
1976. **The Nation's renewable resources—an assessment, 1975.** U.S. Dep. Agric. For. Serv., Washington, D.C.

U.S. National Park Service.
1976. **Public use of the National Park System, CY report, 1975.** Washington, D.C., p. 24.

U.S. National Park Service.
1977. **Overnight stays—1976.** Washington, D.C.

U.S. National Park Service.
1978. **Statistical abstract, 1977.** U.S. Gov. Print. Off., Washington, D.C., p. 2.

U.S. Outdoor Recreation Resources Review Commission.
1962. **Outdoor recreation for America.** U.S. Gov. Print. Off., Washington, D.C. p. 6.

U.S. Senate.
1977. **Report of the ascertained need of the state and local government and private sectors of the tourism and travel industry.** Committee Print 89-959. U.S. Gov. Print. Off., Washington, D.C., p. 53.

U.S. Senate.
1978. **National tourism policy study, final report.** Committee Print. U.S. Gov. Print. Off., Washington, D.C.

U.S. Soil Conservation Service.
1977. **Recreation ready reference.** U.S. Dep. Agric. Soil Conserv. Serv. Northeast Tech. Serv. Cent., Broomall, Pa.

U.S. Travel Data Center.
1977. **1976 National travel survey: full year report.** Washington, D.C.

U.S. Travel Data Center.
1979. **Travel printout, April 1978–January 1979.** Washington, D.C.

Woodall Publishing Company.
1978. **Woodall's campground directory, 1977.** (North American edition.) Highland Park, Ill.

# APPENDIX

**Disaggregation of travel regions used by the U.S. Travel Data Center**

1. New England
   - Connecticut
   - Maine
   - Massachusetts
   - New Hampshire
   - Rhode Island
   - Vermont
2. Eastern Gateway
   - New Jersey
   - New York
3. G. Washington Country
   - Delaware
   - District of Columbia
   - Maryland
   - Pennsylvania
   - Virginia
   - West Virginia
4. South
   - Alabama
   - Arkansas
   - Florida
   - Georgia
   - Kentucky
   - Louisiana
   - Mississippi
   - North Carolina
   - South Carolina
   - Tennessee
5. Great Lakes Country
   - Illinois
   - Indiana
   - Iowa
   - Michigan
   - Minnesota
   - Ohio
   - Wisconsin
6. Mountain West
   - Colorado
   - Montana
   - Nebraska
   - North Dakota
   - South Dakota
   - Utah
   - Wyoming
7. Frontier West
   - Arizona
   - Kansas
   - Missouri
   - New Mexico
   - Oklahoma
   - Texas
8. Far West and Hawaii
   - Alaska
   - California
   - Idaho
   - Nevada
   - Oregon
   - Washington
   - Hawaii

NCOA Campground Occupancy Index
P.O. Box 640
Durham, NH 03824

Campground No. _____ Total developed sites: _____

Sites rented for the season: _____

Week beginning: _____

| | Sun. | Mon. | Tues. | Wed. | Thurs. | Fri. | Sat. |
|---|---|---|---|---|---|---|---|
| No. of vacant sites: | _____ | _____ | _____ | _____ | _____ | _____ | _____ |
| No. of parties using over-flow area (if any) : | _____ | _____ | _____ | _____ | _____ | _____ | _____ |

## 1978 CAMPGROUND REPORT CARD

Campground No. 272 Date _____

Please rate us on the following. Give us an A (for excellent), B (if better than average), C (average), D (below average) and E (poor).

| | A | B | C | D | E |
|---|---|---|---|---|---|
| Your first impression | | | | | |
| Cleanliness of campsites | | | | | |
| Cleanliness of restrooms | | | | | |
| Privacy of campsites | | | | | |
| Good size of campsites | | | | | |
| Good choice of campsites | | | | | |
| Availability of firewood | | | | | |
| Availability of supplies | | | | | |
| Recreation opportunities | | | | | |
| Ease of check-in (speed) | | | | | |
| Safety and security | | | | | |
| Good rules/regulations | | | | | |
| Helpfulness of employees | | | | | |
| Your recommendation of us | | | | | |

May we have your zip code? _____

THANKS — Please mail your completed report card today and have a good camping trip.

**The Management**

**NATIONAL CAMPER SATISFACTION INDEX**

FIRST CLASS
PERMIT NO. 33
BURLINGTON, VERMONT

**BUSINESS REPLY FORM**

NO POSTAGE STAMP NECESSARY IF MAILED IN UNITED STATES

POSTAGE WILL BE PAID BY

DEPARTMENT OF AGRICULTURAL & RESOURCE ECONOMICS
178 SOUTH PROSPECT STREET
BURLINGTON
VERMONT 05401

## Survey of 12 National Camping Leaders

VERMONT AGRICULTURAL EXPERIMENT STATION
Department of Agricultural and Resource Economics
University of Vermont
178 South Prospect Street
Burlington, Vermont 05401

Please look into your crystal ball and try to visualize the camping situation in 1985. Check the most appropriate space when responding to questions 1 to 12.

1. The total number of people camping will probably:

   Increase 11 Remain the same 1 Decrease 0

2. The population mix who will camp at developed campgrounds in 1985 as a percent of all campers will:

| Type | Increase | Same | Decrease |
|---|---|---|---|
| Families with young children | 7 | 4 | 1 |
| Families with teenagers | 2 | 9 | 1 |
| Families without children (excluding retirees) | 8 | 3 | 1 |
| Retirees | 11 | 1 | 0 |

3. Comparing 1985 with today, the percentage of the total U.S. population camping at the following types of areas will:

| Type of area | Increase | Same | Decrease |
|---|---|---|---|
| Private developed campgrounds | 10 | 2 | 0 |
| Public developed campgrounds | 3 | 6 | 3 |
| Public undeveloped backcountry areas | 9 | 1 | 2 |

4. Comparing the 1985 camper with the camper of today:

| | As a percent of all campers will | | |
|---|---|---|---|
| Camper characteristic | Increase | Same | Decrease |
| Use some type of RV | 7 | 3 | 2 |
| Want convenience and service | 7 | 5 | 0 |
| Want unorganized recreation at the campground | 7 | 4 | 1 |
| Want organized recreation at the campground | 5 | 6 | 1 |
| Want an environmental education program | 2 | 8 | 2 |
| Want natural water swimming | 4 | 3 | 5 |
| Want swimming pool | 6 | 6 | 0 |

5. Typical family camping trips in 1985:

| Trip characteristic | 1985 as compared to 1977 | | |
|---|---|---|---|
| Number of trips per family | More 7 | Same 1 | Fewer 4 |
| Distance traveled per trip | Greater 0 | Same 2 | Less 10 |
| Days of camping per trip | More 9 | Same 1 | Fewer 2 |
| Number of campgrounds visited per trip | More 2 | Same 2 | Fewer 9 |

6. Typical camping fees to expect in 1985:

| Type of site | Most likely fee to expect, 1985 ($) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 15+ | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 or less |
| 1. Private campground with pool and electricity and water at each site | 2 | | 1 | 4 | 2 | 3 | | | | |
| 2. Public campground on water body with electricity and water at each site | | 1 | | 1 | | 2 | 3 | 2 | 1 | 2 |
| 3. Public campground with no swimming and no electricity and no water at each site* | | | | 1 | | 1 | | | 3 | 6 |

7. Typical midsummer campground occupancy rates to expect in 1985:

| Type of campground | Occupancy rate--Midsummer (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 100 | 90 | 80 | 70 | 60 | 50 | 40 | 30 or less |
| Typical National Park campground* | 7 | 4 | | | | | | |
| Typical National Forest campground* | 2 | 3 | 3 | 2 | | 1 | | |
| Typical private independent campground | | 2 | 5 | 4 | | 1 | | |
| Typical private franchise campground | | 7 | 3 | 1 | 1 | | | |

*One person did not respond to this category therefore the total adds to 11 and not 12.

8. Typical private campground management policies to expect in 1985:

| Policy | 1985 as compared to 1977 | | |
|---|---|---|---|
| 1. Development of new campgrounds | Greater rate 3 | Same 3 | Slower rate 6 |
| 2. Expansion of existing campgrounds | Greater rate 5 | Same 6 | Slower rate 1 |
| 3. Nonfranchise campgrounds tied into nationwide reservation system | Likely 4 | Possible 6 | Unlikely 2 |
| 4. Rental of sites for full season | More 11 | Same 1 | Less 0 |
| 5. Rental of stationary RV at campground | More 8 | Same 4 | Less 0 |
| 6. Sale of site in condominium campground | More 10 | Same 1 | Less 1 |
| 7. Off-season equipment storage area at campground | More 12 | Same 0 | Less 0 |
| 8. Provision of recreation programs and facilities | More 10 | Same 2 | Less 0 |
| 9. Development of organized social programs | More 8 | Same 3 | Less 1 |

9. Typical public campground management policies to expect in 1985:

| Policy | 1985 as compared to 1977 | | |
|---|---|---|---|
| 1. Development of new campgrounds | Greater rate 1 | Same 4 | Slower rate 7 |
| 2. Expansion of existing campgrounds | Greater rate 1 | Same 7 | Slower rate 4 |
| 3. Electricity and water at each site | More 3 | Same 7 | Less 2 |
| 4. Policy of reservations only | More 4 | Same 5 | Less 3 |
| 5. Environmental education programs | More 7 | Same 4 | Less 1 |
| 6. Organized recreation programs | More 5 | Same 3 | Less 4 |
| 7. Privately-operated concessions | More 10 | Same 1 | Less 1 |
| 8. Construction of campgrounds closer to population centers | More 8 | Same 3 | Less 1 |
| 9. Fees that will cover both capital and operating costs | More common 6 | Same 5 | Less common 1 |
| 10. Separation of RV sites from tent sites within single campground | More common 8 | Same 2 | Less common 2 |

10. Should public agencies that currently manage "backcountry areas" construct campgrounds providing showers, toilets, supplies, information, etc., for backpackers? Yes 4 No 8

11. Should public agencies that currently manage trail systems develop hut systems providing lodging and mean services on heavily-used trails? Yes 5 No 7

Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories and research units are maintained at:

- Amherst, Massachusetts, in cooperation with the University of Massachusetts.
- Beltsville, Maryland.
- Berea, Kentucky, in cooperation with Berea College.
- Burlington, Vermont, in cooperation with the University of Vermont.
- Delaware, Ohio.
- Durham, New Hampshire, in cooperation with the University of New Hampshire.
- Hamden, Connecticut, in cooperation with Yale University.
- Kingston, Pennsylvania.
- Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
- Orono, Maine, in cooperation with the University of Maine, Orono.
- Parsons, West Virginia.
- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- University Park, Pennsylvania, in cooperation with the Pennsylvania State University.
- Warren, Pennsylvania.

GOV'T. DOCUMENTS
DEPOSITORY ITEM
SEP 26 1979
CLEMSON
LIBRARY

# Guide to the Measurement of TREE CHARACTERISTICS Important to the QUALITY CLASSIFICATION SYSTEM for YOUNG HARDWOOD TREES

CLEMSON UNIVERSITY LIBRARY
SEP 26 1979
SCI., TECH. & AGR. DIV.

by David L. Sonderman

**FOREST SERVICE GENERAL TECHNICAL REPORT NE-54**
**1979**
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
370 REED ROAD, BROOMALL, PA. 19008

## The Author

DAVID L. SONDERMAN, research forest products technologist, received a B.S. degree in forestry from West Virginia University in 1962. He joined the Northeastern Forest Experiment Station in June 1962, and was on the staff of the eastern softwood timber quality project until June 1972. He is currently with the Northeastern Station's project on quality and grade of hardwood timber, Delaware, Ohio.

MANUSCRIPT RECEIVED FOR PUBLICATION 19 MARCH 1979

## Abstract

A procedure is shown for measuring external tree characteristics that are important in determining the current and future quality of young hardwood trees. This guide supplements a previous study which describes the quality classification system for young hardwood trees.

AS A SUPPLEMENT to the quality classification system for young hardwood trees (Sonderman and Brisbin 1978), we have developed this guide to illustrate how to select and measure quality-related tree characteristics that are important in the classification system. Forest managers need this information in selecting and culturing potential high-value hardwood trees from regeneration through final harvest.

Systematically measuring the external characteristics of a tree to determine current quality establishes a solid base for predicting the future product potential of young hardwood stands.

## RELATIVE QUALITY INDEX

As part of the overall quality classification system, we have developed relative quality indexes which are used to quickly rank trees as good, medium, or poor. The relative quality index is derived from numerical values or points assigned to the external characteristics of a tree (Table 1). These characteristics include crown class, sweep and crook, total number of limbs, forks, and rot and seams (Fig. 1). When a tree is evaluated for these characteristics, the individual numerical indexes are summed to produce the following quality classes:

| *Sum of individual indexes* | *Relative quality class* |
|---|---|
| 10-12 | Good |
| 8-9 | Medium |
| 1-7 | Poor |

These indexes were formulated from field tests on numerous trees of varying quality.

## AS AN OPERATIONAL GUIDE

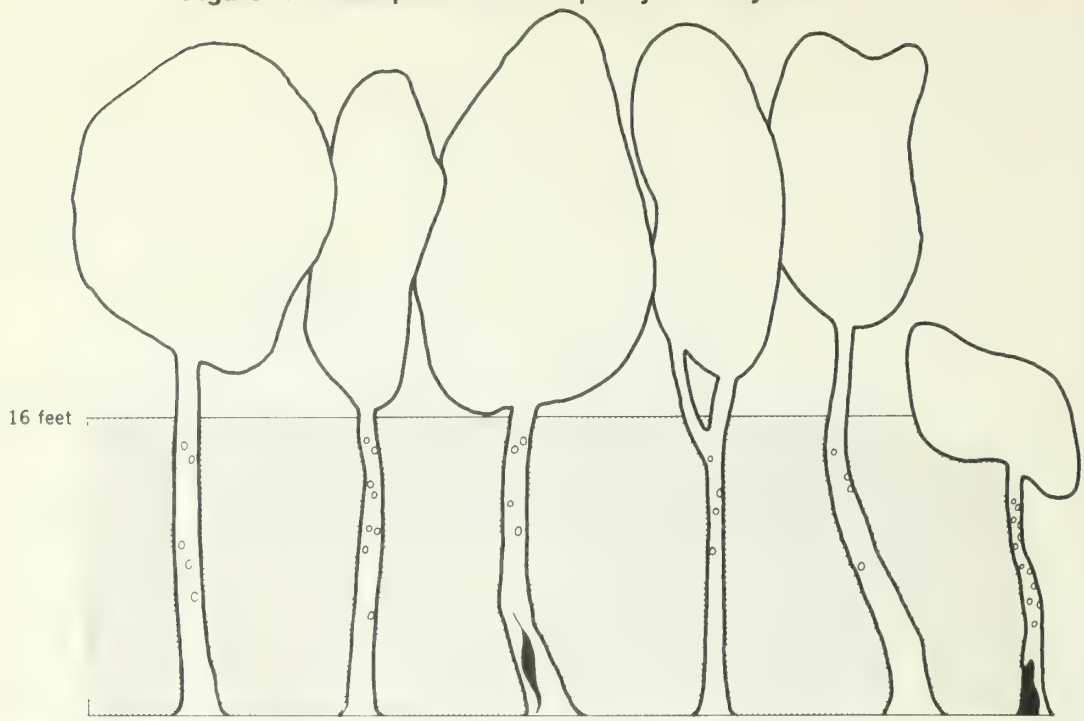
The quality classification system can be used as an operational guide and applied in several ways. Subsampling techniques could be used to estimate the means and variances of individual tree characteristics. Area sampling could be used to estimate the proportion of trees or the proportion of area stocked with trees that have certain characteristics. An average index could be estimated for stands or strata within stands to aid in making decisions on cultural treatment.

**Table 1.—Numerical values assigned to selected tree characteristics to determine tree quality indexes**

| Characteristics | Value |
|---|---|
| Crown class | |
| Dominant | 4 |
| Codominant | 3 |
| Intermediate | 2 |
| Suppressed | 1 |
| Sweep and crook (deviation in inches)[a] | |
| 1 | 4 |
| 2-4 | 3 |
| 5-6 | 2 |
| 7-8 | 1 |
| 9+ | 0 |
| Limb count (No. live and dead limbs ≧ 1/3 inch) | |
| 1-2 | 4 |
| 3-4 | 3 |
| 5-8 | 2 |
| 9-16 | 1 |
| 17+ | 0 |

[a]If tree has fork, rot, or seams, the numerical value is 0.

**Figure 1.—Example of relative quality index system.**




| | | | | | |
|---|---|---|---|---|---|
| CROWN CLASS: | DOMINANT 4 | INTERMEDIATE 2 | DOMINANT 4 | CODOMINANT 3 | CODOMINANT 3 | SUPPRESSED 1 |
| SWEEP and CROOK: | NO SWEEP 4 | 2" SWEEP 3 | *5" SWEEP (SEAM) 0 | *NO SWEEP (FORK) 0 | 6" SWEEP 2 | *4" SWEEP (ROT) 0 |
| LIMBS: | 5 LIMBS 2 | 8 LIMBS 2 | 4 LIMBS 3 | 4 LIMBS 3 | 4 LIMBS 3 | 12 LIMBS 1 |
| REL. QUAL. INDEX: | 10 | 7 | 7 | 6 | 8 | 2 |

* IF TREE HAS FORK, ROT, OR SEAM, THEN QUALITY INDEX VALUE = 0

The small woodlot owner could apply the tree quality classification system to his stand. By carefully following the instructions in this guide in measuring tree characteristics and observing them over time, he can accurately assess the quality of each tree. This information would be useful in deciding whether to culturally treat a stand or do nothing.

## TREE CHARACTERISTICS THAT AFFECT QUALITY

The quality of young hardwood trees is determined primarily by the condition, size, and frequency of naturally occurring external characteristics. For example, trees with limby and crooked butt sections yield low-quality lumber. Although we used crown class, sweep and crook, total number of live and dead limbs, forks, and rot and seams in determining tree quality indexes, additional variables must be measured to make quantitative estimates of future product potential. These include crown ratio, tree height, size of limbs, overgrowths, epicormic branches, and overgrowths with associated epicormic branches.

Each of these tree characteristics was selected because of its consistent relationship with use requirements for most of today's products.

## HOW TO MEASURE TREE CHARACTERISTICS

The following are the characteristics that we measured or estimated and intend to observe over time. Numerical designations for each variable are recorded on the sample tally sheet (Fig. 2).

**Figure 2.—Example of tree data tally sheet.**

| TREE NO. | SPECIES | DBH (IN) | CROWN CLASS | CROWN RATIO | TOTAL HT (FT) | FORK HT (FT) | SWEEP/ CROOK (IN) | ROT/SEAM FACES (NO) | ROT/SEAM LEN. (FT) | SURFACE DEFECT 0' to 8' LIVE (NO) | LIVE (SIZE) | DEAD (NO) | DEAD (SIZE) | OVER (NO) | OVER (EPIC) | | SURFACE DEFECT 8' to 16' LIVE (NO) | LIVE (SIZE) | DEAD (NO) | DEAD SIZE) | OVER (NO) | OVER (EPIC) | | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| XXX | XXX | XXX | X | XX | XXX | XX | XX | X | XXXX | XX | XXX | XX | XXX | XX | XX(A) | X(B) | XX | XXX | XX | XXX | XX | XX(A) | X(B) | |
| 047 | 001 | 063 | 2 | 40 | 072 | 15 | 04 | 1 | 0105 | 04 | 250 | 00 | 000 | 02 | 02 | 1 | 00 | 000 | 00 | 000 | 00 | 00 | 0 | |

FOREST_____ LOCATION_____ PLOT NO._____ GRADER_____ SHEET_____OF_____

### Tree number

Record the tree number as painted or tagged on the tree. Record as 3 digit code. EXAMPLE: Tree number is 47—enter 047 in "Tree No." column.

### Species

Record the appropriate tree species as a 3 digit code. (See Appendix.) EXAMPLE: Species is white oak—enter 001 in "Species" column.

### Diameter at breast height

Measure all trees 3.5 inches or larger in diameter at breast height to the nearest 1/10 inch and record as a 3 digit code. EXAMPLE: Dbh is 6.3 inches—enter 063 in "Dbh" column.

### Crown class

Crown class (Fig. 3) includes the following categories:

*Dominant* (Code 1). Trees with well-developed crowns extending above the general level of the crown cover and receiving full light from above and partial light from the sides; the crowns may be somewhat crowded on the sides. A dominant tree is larger than the average tree in the stand.

*Codominant* (Code 2). Trees with medium-size crowns forming the general level of the crown cover and receiving full light from above, but little from the sides. The crowns usually are somewhat crowded on the sides.

*Intermediate* (Code 3). Trees with small crowns that are below or that extend into the crown cover formed by codominant and dominant trees. The crowns receive little direct light from above and none from the sides; and usually are crowded considerably on the sides.

*Suppressed* (Code 4). Trees with crowns entirely below the general level of the crown cover; the crowns receive no direct light either from above or from the sides.

Crown class is recorded as a single digit code. EXAMPLE: Tree is in the codominant crown class—enter 2 in "Crown Class" column.

**Figure 3.—Crown class.**

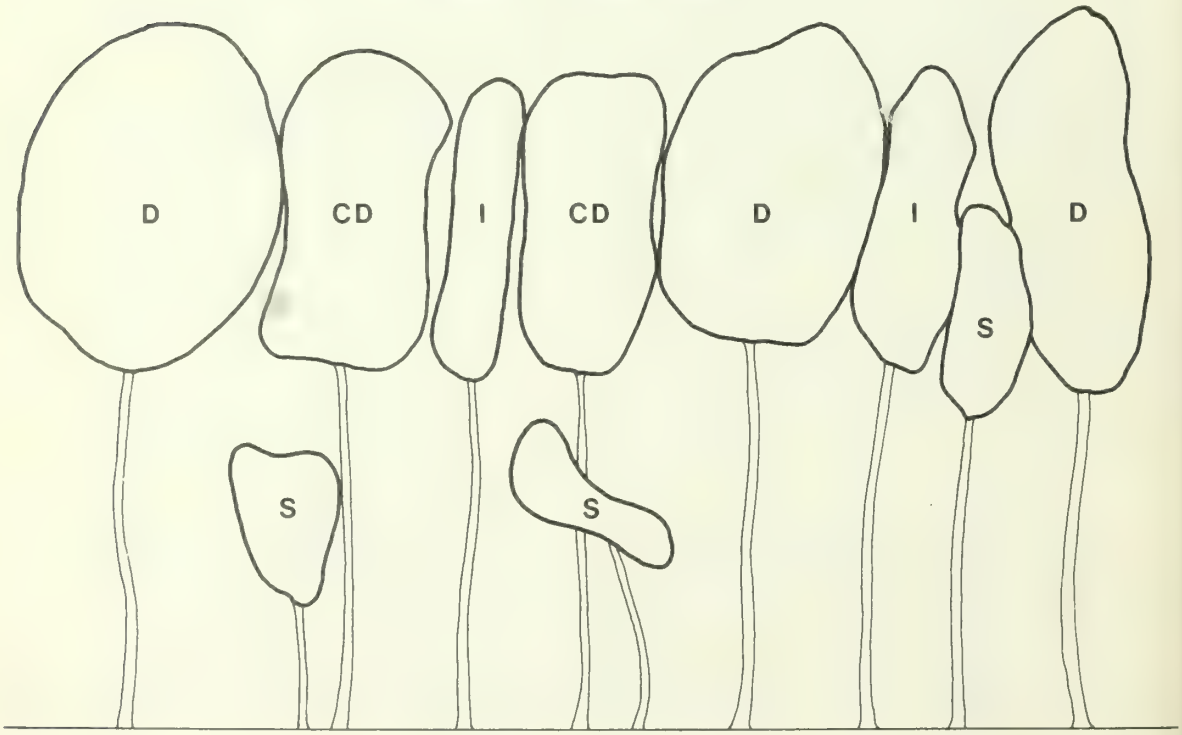
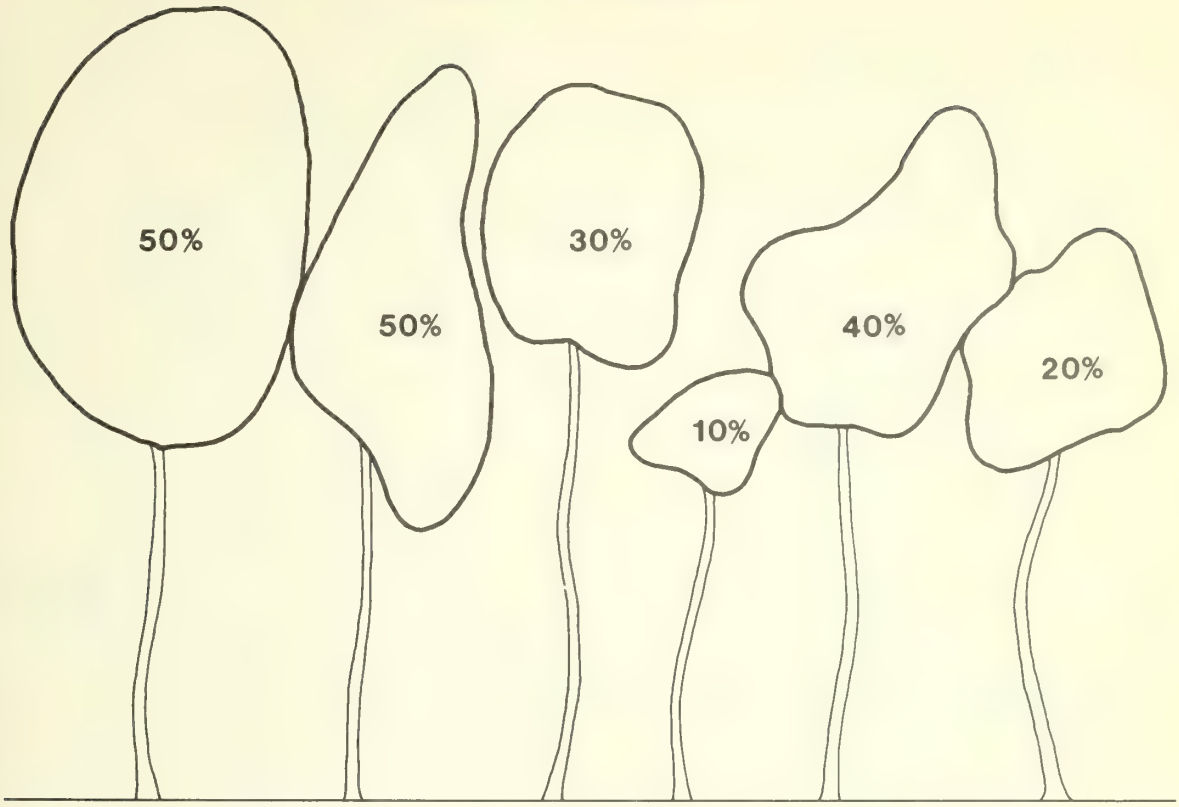


Figure 4.—Crown ratio.




## Crown ratio

Crown ratio (Fig. 4) is that portion of the tree bole that supports live green foliage which contributes to tree growth. Crown ratio is expressed as percent of total tree height to the *nearest 10 percent* and recorded as a 2 digit code. For trees of uneven crown length, visually transfer lower branches on the longer side to fill holes in the upper portion until the crown is full and even. EXAMPLE: The crown ratio is estimated to be 40 percent—enter 40 in "Crown Ratio" column.

## Total height

Use an appropriate instrument to measure total height (Fig. 5) from a 1-foot stump to the top of the tree. Measure to the nearest foot and record as 3 digit code. EXAMPLE: Total tree height is 72 feet—enter 072 in "Total Height" column. For trees with forks, measure from a 1-foot stump to the top of the largest forked section and record in "Total Height" column. If the tree forks *below* the 1-foot stump (as in sprout growth), consider as *two* trees.

## Fork height

For forked trees (Fig. 6), measure the fork height (butt 16 feet of the tree only) from a 1-foot stump to the center of the first main fork. Record as a 2 digit code. EXAMPLE: Fork height measures 15 feet—enter 15 on "Fork Height" column.

A fork results from the division of the main stem into two or more stems. Each of the resulting stems must be at least ½ the diameter of the main stem just below the fork. Trees with exceptionally large single limbs and not qualifying as a fork will be noted in the "Comments" column, and *will not* be tallied as single largest live or dead limbs (under "Surface Defects" column).

Figure 5.—Total height.

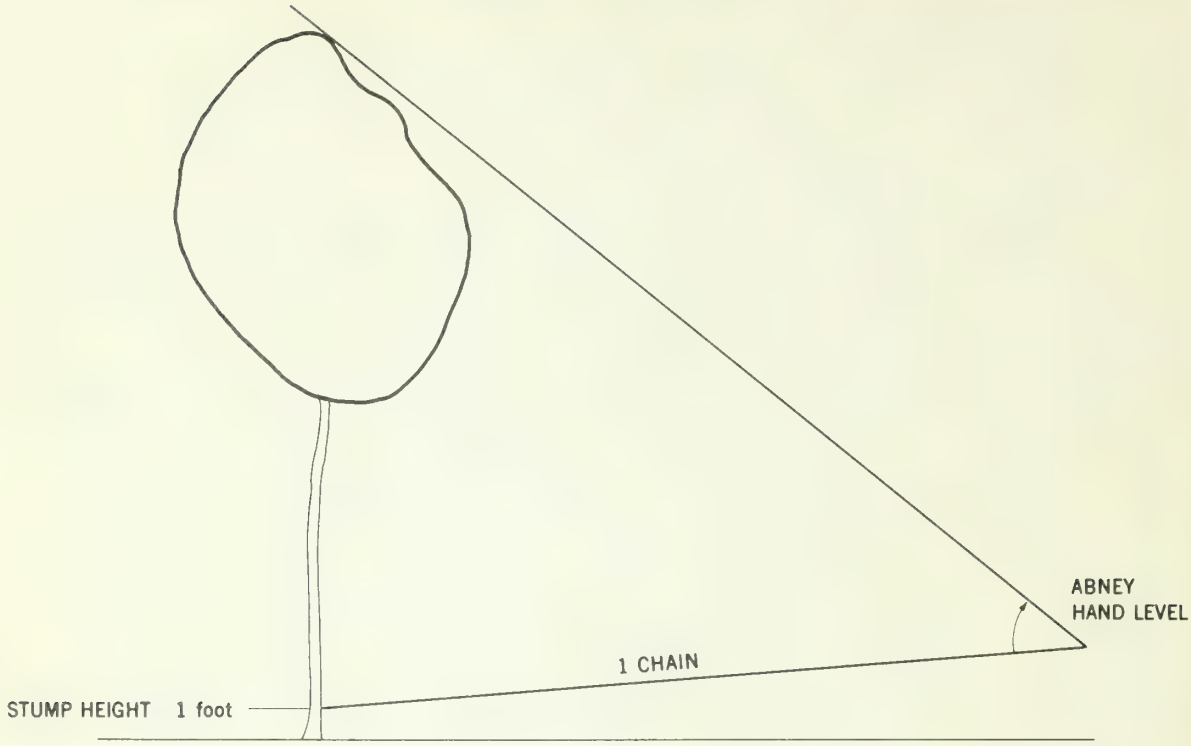
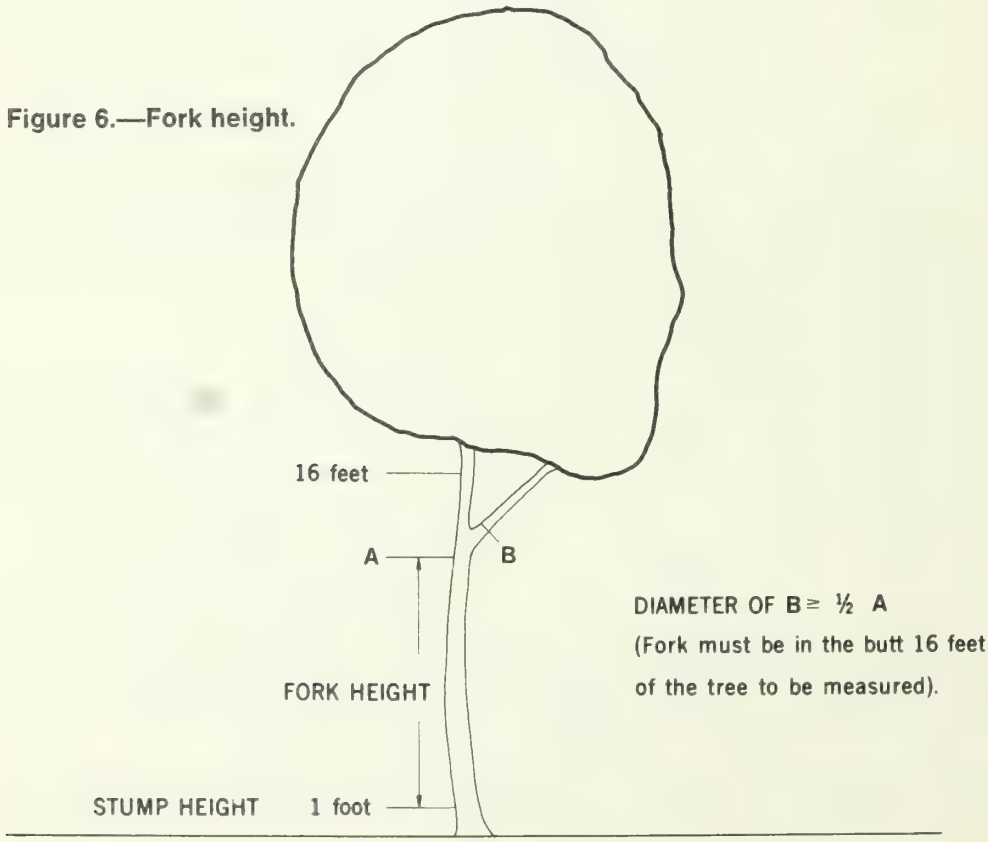



Figure 6.—Fork height.



Sonderman, David L.
1979. **Guide to the measurement of tree characteristics important to the quality classification for young hardwood trees.** Northeast. For. Exp. Stn., Broomall, Pa.
12 p., illus. (USDA For. Serv. Gen. Tech. Rep. NE-54)

A procedure for measuring external tree characteristics that are important in determining the current and future quality of young hardwood trees. This guide supplements Forest Service Research Paper NE-419, which describes the quality classification system for young hardwoods.

851--852.11--852.12--853

**Keywords:** tree characteristics, quality classification

Sonderman, David L.
1979. **Guide to the measurement of tree characteristics important to the quality classification for young hardwood trees.** Northeast. For. Exp. Stn., Broomall, Pa.
12 p., illus. (USDA For. Serv. Gen. Tech. Rep. NE-54)

A procedure for measuring external tree characteristics that are important in determining the current and future quality of young hardwood trees. This guide supplements Forest Service Research Paper NE-419, which describes the quality classification system for young hardwoods.

851--852.11--852.12--853

**Keywords:** tree characteristics, quality classification

Sonderman, David L.
1979. **Guide to the measurement of tree characteristics important to the quality classification for young hardwood trees.** Northeast. For. Exp. Stn., Broomall, Pa.
12 p., illus. (USDA For. Serv. Gen. Tech. Rep. NE-54)

A procedure for measuring external tree characteristics that are important in determining the current and future quality of young hardwood trees. This guide supplements Forest Service Research Paper NE-419, which describes the quality classification system for young hardwoods.

851--852.11--852.12--853

**Keywords:** tree characteristics, quality classification

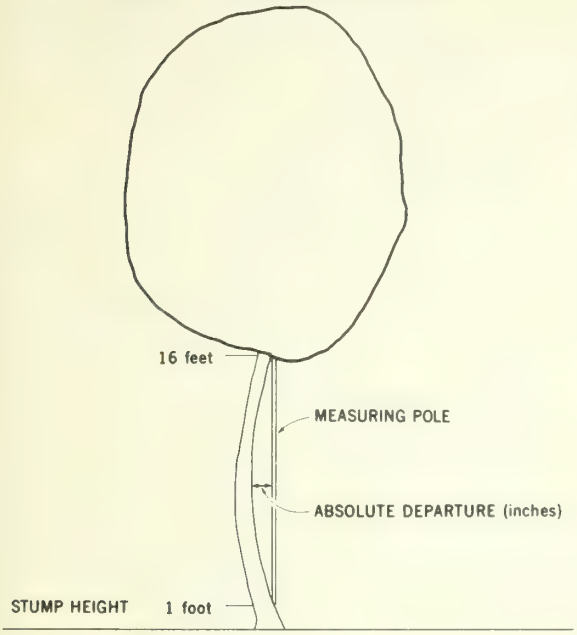
Sonderman, David L.
1979. **Guide to the measurement of tree characteristics important to the quality classification for young hardwood trees.** Northeast. For. Exp. Stn., Broomall, Pa.
12 p., illus. (USDA For. Serv. Gen. Tech. Rep. NE-54)

A procedure for measuring external tree characteristics that are important in determining the current and future quality of young hardwood trees. This guide supplements Forest Service Research Paper NE-419, which describes the quality classification system for young hardwoods.

851--852.11--852.12--853

**Keywords:** tree characteristics, quality classification

Figure 7.—Sweep and crook.




## Sweep and crook

Measure the departure (offset) in inches of sweep or crook (Fig. 7) in the butt 16 feet of the tree and record as a 2 digit code. EXAMPLE: Sweep is 4 inches—enter 04 in "Sweep/Crook" column.

## Rot and seams

Consider rot and seams (Fig. 8) in the butt 16 feet of the tree. Visually square the butt 16 feet of the tree into four faces to include as many indicators in one face as possible. Examine each face and *count* the number of faces affected and record as a single digit code. EXAMPLE: One face is affected—enter 1 in the "Faces" column under "Rot/Seam."

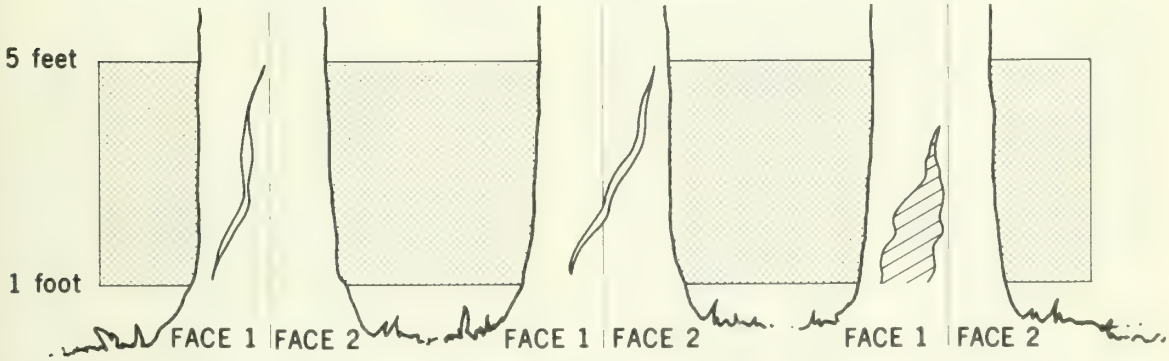
Now measure the length affected from starting point to end point on each face and record the minimum and maximum height as a 4 digit code. Measurements are taken from a 1-foot stump. EXAMPLE: The length affected extends from 1 foot to 5 feet—enter 0105 in "Length" column under "Rot/Seam."

## Surface defects

For each 8-foot section of the butt 16 foot log, tally all trees ≥3.5 inches as follows: *Count* the number of live and dead limbs ≥1/3 inch in diameter (Figs. 9 and 9a). Record as a 2 digit code. EXAMPLE: Upper 8-foot section has four live limbs ≥1/3 inch—enter 04 in "Number" column under "Surface Defect" (Live).

Now *measure* or *estimate* the size (to the nearest ¼ inch) of the single largest qualify-

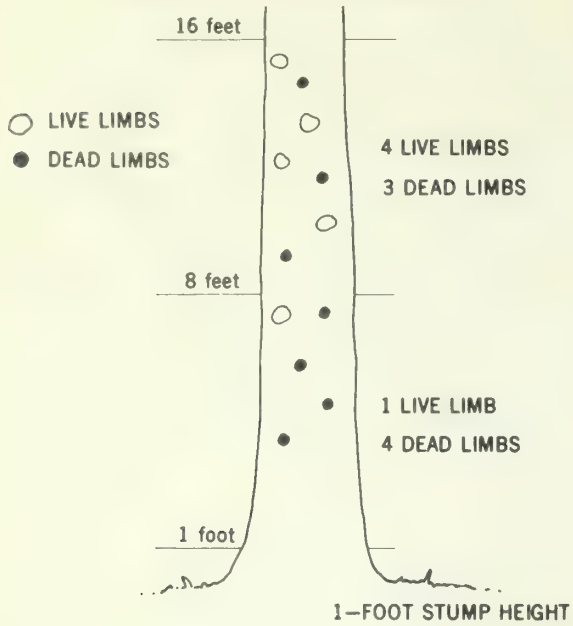
Figure 8.—Rot and seams.




| ONE FACE AFFECTED: | TWO FACES AFFECTED: | ONE FACE AFFECTED: |
|---|---|---|
| LENGTH FROM 1 foot to 5 feet | LENGTH FACE ONE 1 foot to 3 feet<br>LENGTH FACE TWO 3 feet to 5 feet | LENGTH FROM 1 foot to 3 feet |

Note: MEASUREMENTS TAKEN FROM 1—FOOT STUMP HEIGHT

Figure 9.—Surface defects.




ing live and single largest qualifying dead limb. Record as a 3 digit code. EXAMPLE: Single largest live limb is 2.5 inches—enter 250 in "Size" column.

## Overgrowths

A measurable overgrowth (Fig. 10) is the result of a defect caused by a branch stub or insect damage. For example, if a branch has fallen off recently, the branch stub will be exposed—this is considered a dead branch rather than an overgrowth. However, a scar will be visible if the branch stub has been covered over by callous material. If this scar is at least 1 inch in diameter and protrudes ¼ inch from the main stem, it is considered a measurable overgrowth and should be counted. Overgrowths on trees 6.0 inches or larger in dbh are likely to cause product defects because they usually extend into the quality zone.

Figure 9a.—Dead limb $\geq$ ⅓ inch.

Figure 10.—Overgrowth (measurable).

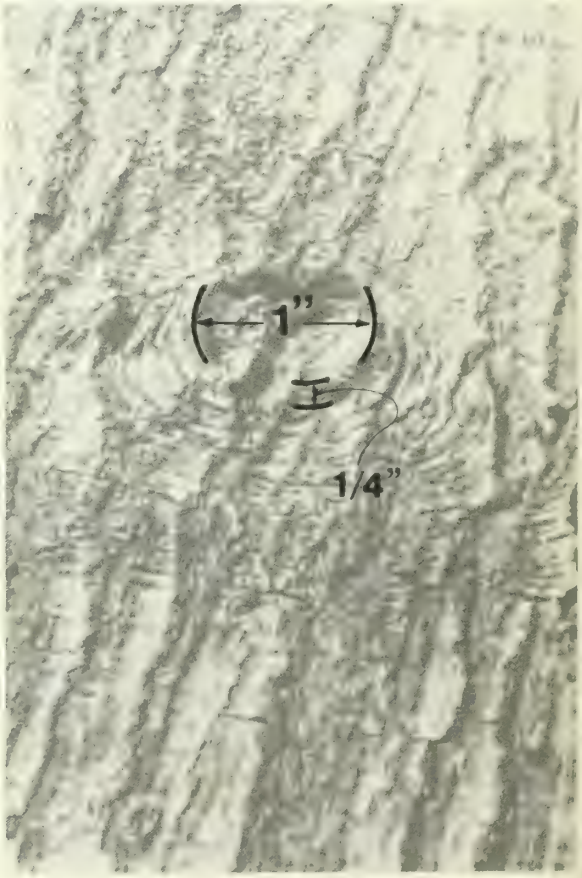


Figure 11.—Overgrowths.

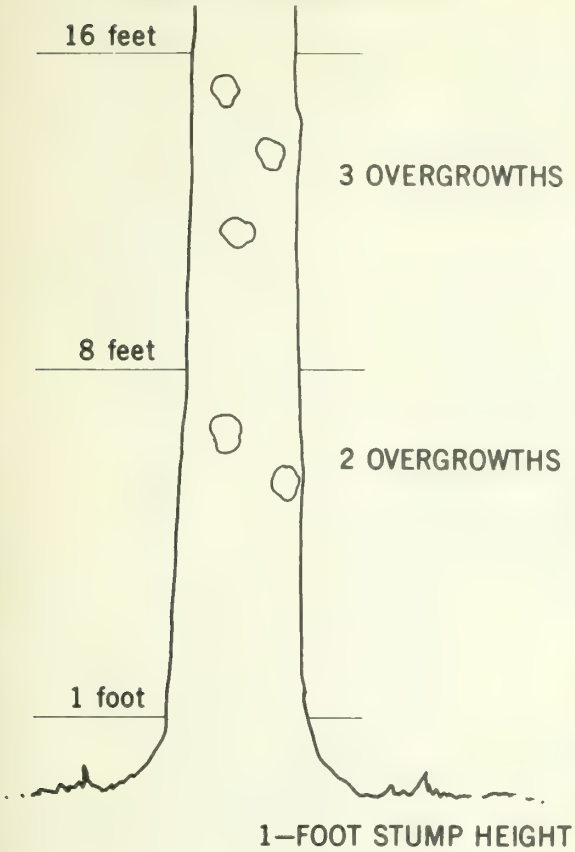
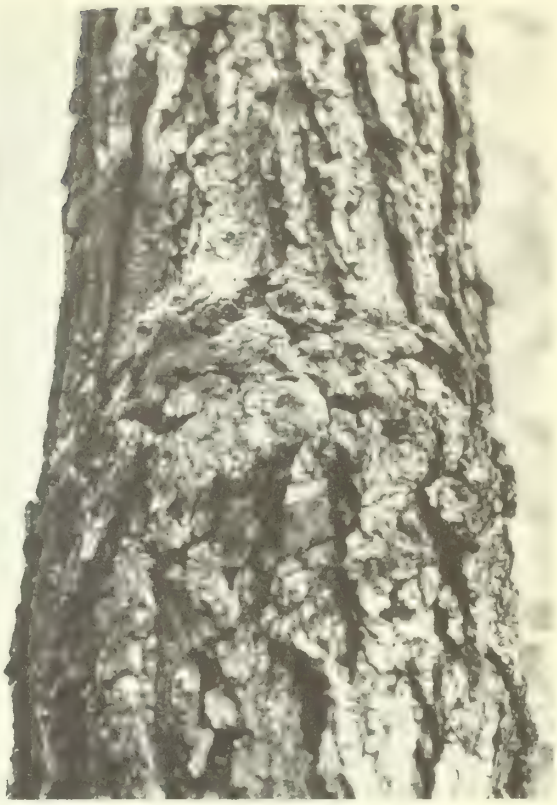



Figure 11a.—Overgrowth.



For each 8-foot section of trees 6.0 inches and larger in dbh, count the number of overgrowths (Figs. 11 and 11a) and record as a 2 digit code. EXAMPLE: Tree contains 2 overgrowths in the first 8-foot section—enter 02 in "Number" column under "Surface Defect" (Overgrowths).

## Overgrowths with associated epicormic branches

For each 8-foot section of the butt 16 feet of the tree, *count* the number of overgrowths that are surrounded by related epicormic branches (Figs. 12 and 12a). Record as a 2 digit code. EXAMPLE: Two overgrowths have related epicormic branches—enter 02 in "Epic A" column under "Surface Defect" (Overgrowths).

Figure 12.—Overgrowths with associated epicormic branches.

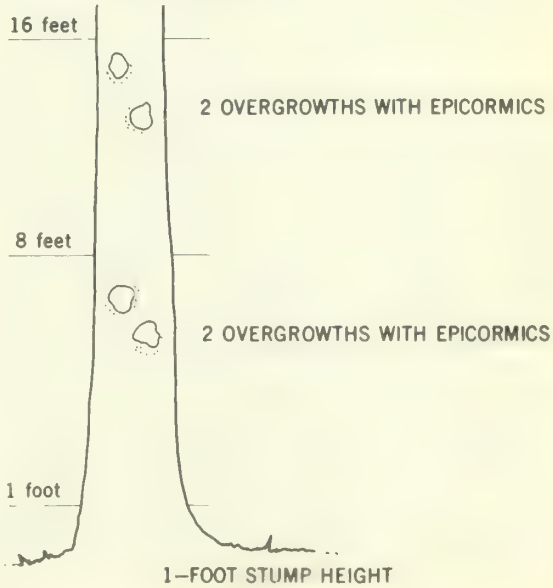


Figure 12a.—Overgrowths with associated epicormic branches.

Figure 13.—Single epicormic branches not associated with overgrowths.

## Epicormic branches/bundles not associated with overgrowths

Epicormic branches are small branches which push through crevices in the bark; many grow rapidly but few develop into a major branch (Fig. 13). Epicormic branches found in small tufts of six or more are called epicormic bundles (Fig. 14).

For each 8-foot section of the butt 16 feet of the tree, *count* the number of epicormic branches/bundles that are not associated with a primary limb overgrowth (Fig. 15). Record as one of the following single digit codes:

(0) No epicormic branches/bundles

(1) 1 to 6 epicormic branches/bundles

(2) 7 or more epicormic branches/bundles

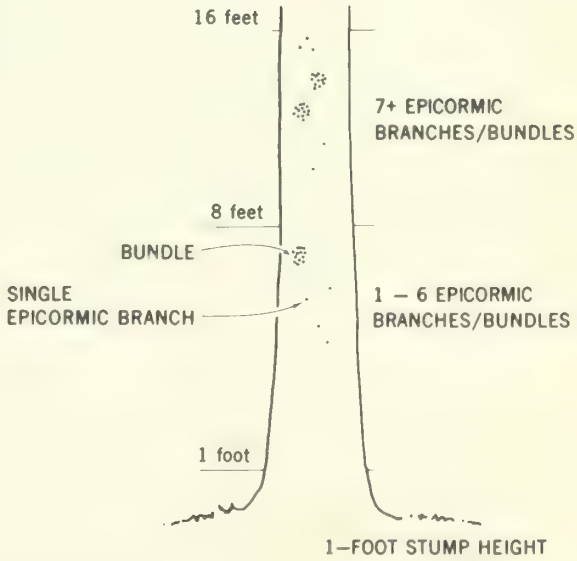
EXAMPLE: An 8-foot section has 5 epicormic branches/bundles—enter 1 in "Epic B" column under "Surface Defect" (Overgrowths).

## LITERATURE CITED

Sonderman, David L., and Robert L. Brisbin. 1978. **A qualty classification system for young hardwood trees—the first step in predicting future products.** USDA For. Serv. Res. Pap. NE-419. 7 p.

**Figure 14.—Epicormic bundle not associated with overgrowths.**

**Figure 15.—Epicormic branches/ bundles not associated with overgrowths.**



# APPENDIX

Species List and Codes

| *Code* | *Species* | *Code* | *Species* |
|---|---|---|---|
| 01 | White oak | 28 | Beech |
| 02 | Black oak | 29 | Ironwood |
| 03 | Scarlet oak | 30 | Bigtooth aspen |
| 04 | Chestnut oak | 31 | Black cherry |
| 05 | Northern red oak | 32 | Red elm |
| 06 | Pin oak | 33 | American chestnut |
| 07 | Blackjack oak | 34 | Hazelnut (including witch-hazel) |
| 08 | Post oak | | |
| 09 | Southern red oak | 35 | Sumac |
| 10 | Yellow-poplar | 36 | Persimmon |
| 11 | Ash | 37 | Virburnum |
| 12 | Hickory | 38 | Redbud |
| 13 | Basswood | 39 | Hawthorn |
| 14 | Black gum | 40 | Black locust |
| 15 | Shortleaf pine | 41 | Shingle oak |
| 16 | Sycamore | 42 | Hackberry |
| 17 | Sweetgum | 43 | Mulberry |
| 18 | Red maple | 44 | Burr oak |
| 19 | Sugar maple | 45 | River birch |
| 20 | Black walnut | 46 | Willow |
| 21 | Hemlock | 47 | Butternut |
| 22 | Cucumber | 48 | Crab apple |
| 23 | Dogwood | 49 | Cottonwood |
| 24 | Sourwood | 50 | Wild-plum |
| 25 | Serviceberry | 51 | Hornbeam |
| 26 | Holly | 52 | Buckeye |
| 27 | Sassafras | | |

☆U.S. GOVERNMENT PRINTING OFFICE: 1979—603-011/44

Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories and research units are maintained at:

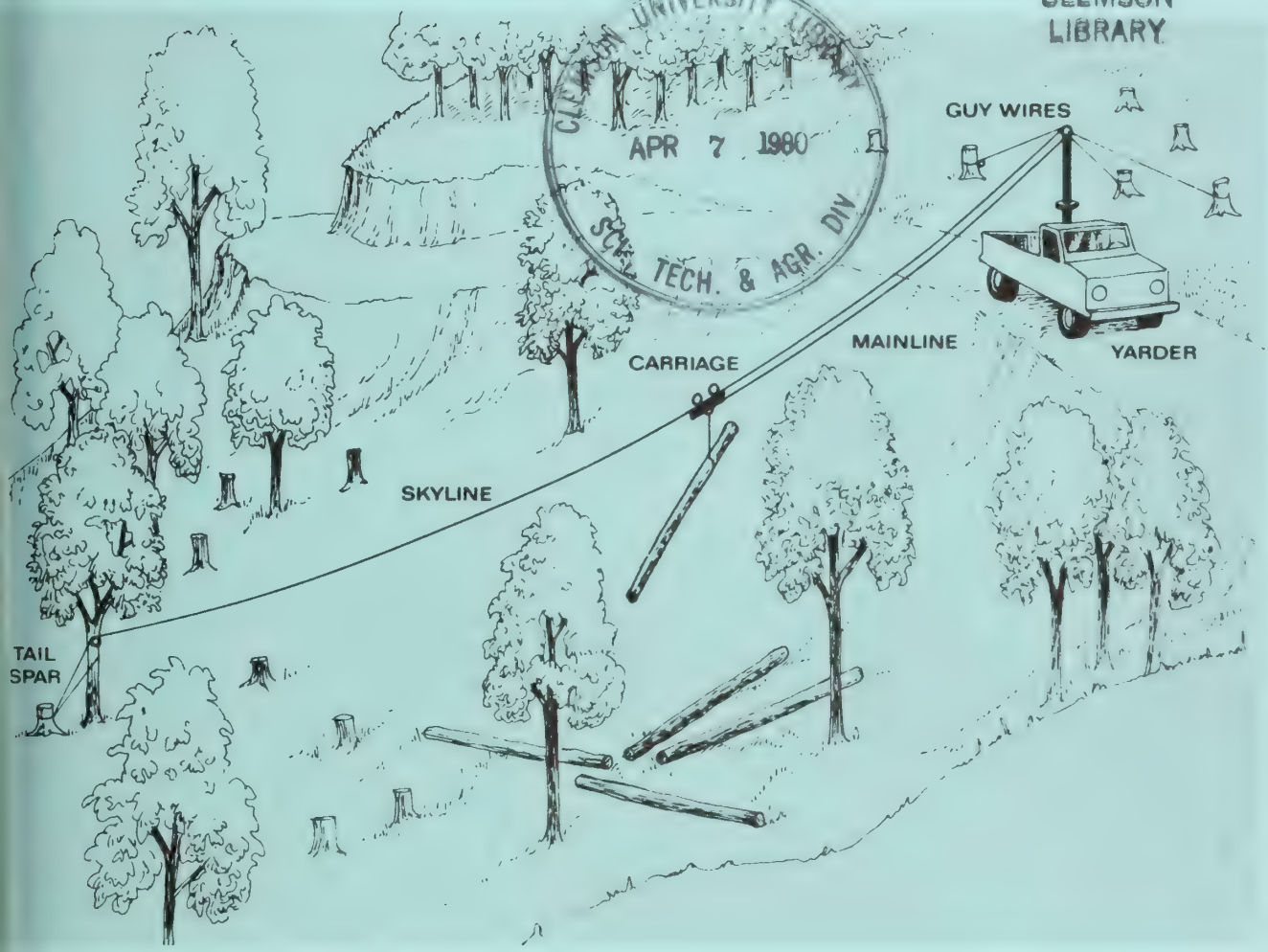
- Amherst, Massachusetts, in cooperation with the University of Massachusetts.
- Beltsville, Maryland.
- Berea, Kentucky, in cooperation with Berea College.
- Burlington, Vermont, in cooperation with the University of Vermont.
- Delaware, Ohio.
- Durham, New Hampshire, in cooperation with the University of New Hampshire.
- Hamden, Connecticut, in cooperation with Yale University.
- Kingston, Pennsylvania.
- Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
- Orono, Maine, in cooperation with the University of Maine, Orono.
- Parsons, West Virginia.
- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- University Park, Pennsylvania, in cooperation with the Pennsylvania State University.
- Warren, Pennsylvania.

by James H. Patric

# SOME ENVIRONMENTAL EFFECTS OF CABLE LOGGING in Appalachian Forests

GOVT. DOCUMENTS
DEPOSITORY ITEM
APR 3 1980
CLEMSON
LIBRARY

CLEMSON UNIVERSITY LIBRARY
APR 7 1980
SCI. TECH. & AGR. DIV.




**FOREST SERVICE GENERAL TECHNICAL REPORT NE-55**
**1980**
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
370 REED ROAD, BROOMALL, PA 19008

## The Author

JAMES H. PATRIC is project leader in forest hydrology research, Timber and Watershed Laboratory, Northeastern Forest Experiment Station, USDA Forest Service, Parsons, West Virginia.

MANUSCRIPT RECEIVED FOR PUBLICATION 22 MAY 1979

## Abstract

The forestry literature, especially from the Eastern United States, was reviewed for reports concerning effects of wood products harvest on forest soil, water, residual stands, wildlife, and visual appeal. In all cases, cable logging caused less unwanted effect on these resources than did other harvest systems. Even though the concept of cable logging is well established, logging machinery built according to this principle, and fully suited to harvesting the eastern hardwood forest, has not been developed.

The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

## INTRODUCTION

FEW CAN DISAGREE that logging—including cable logging—affects the forest environment. But opinion often is divided and strongly held concerning the degree of these effects. Here, one's profession, perspective, prejudices, and even avocation will shape opinion. Does cable logging damage soil and water? Does it help or hinder wildlife and the new generation of trees? Can the visual appeal of purposefully managed young forest compare to that of old-growth timber? Surely, the logger's responses to these questions will differ from those of the recreationist; the city dweller's from his country cousin's. This report reviews the cable logging-environmental literature, particularly for the Eastern United States, and the background of practical woods experience that has stimulated our second look at cable logging in the Appalachian region (Gibson and Biller 1975).

The definitions of cable logging terms used in this paper are taken from Conway (1976). "Skidding" means hauling trees or tree segments along the ground from the stump to a collection point, i.e., landing area. "Ground skidding" means pulling the logs flat across the forest floor; wire ropes and stationary machines are used but there is no capability to lift the logs during the skidding process. The term "yarding" or "cable skidding" implies that the logs are at least partially lifted as they are pulled by wire ropes to collection points. The "high-lead" system of cable logging uses a wire rope suspended from a spar at the collection point. When yarding by the high-lead process, the cable may support little or no weight of the yarded logs, merely dragging them across the forest floor; considerable lift, however, is achieved as the logs approach the spar. The "jammer" is a variation of the high-lead system. With the "skyline," a wire rope is suspended between two or more points; logs suspended from a carriage riding along the skyline may partly drag along the forest floor or they may be fully suspended above it (Fig. 1).

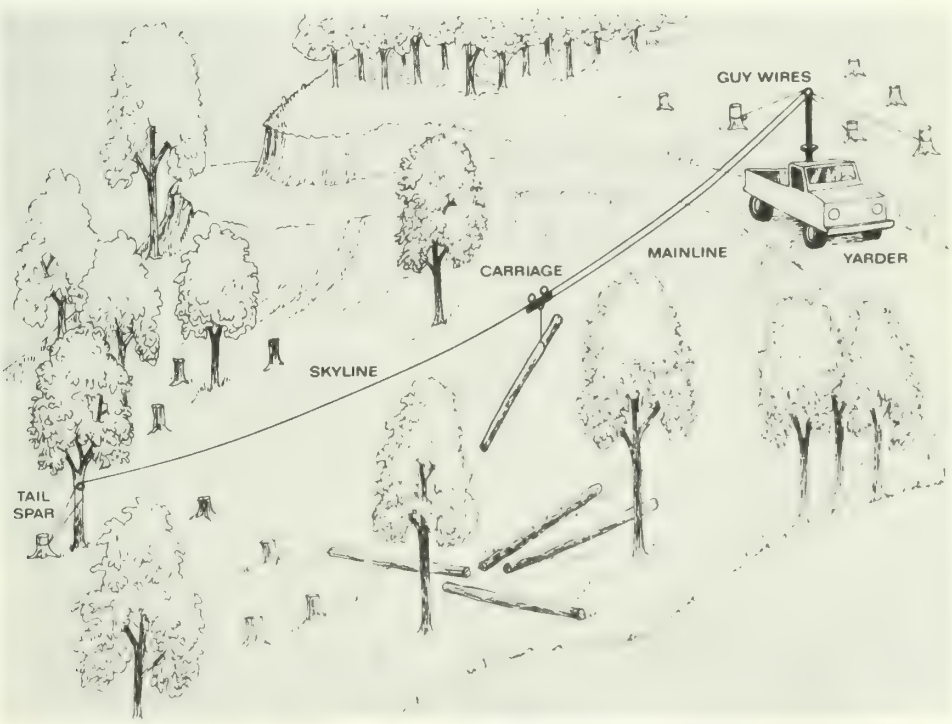



**Figure 1.—Diagram illustrating some operational principles of skyline logging. Other cable logging systems embody similar principles.**

With noncable systems, by contrast, machines or animals travel overland to the logs, then skid the logs across the forest floor to collection points.

## IN DAYS OF YORE

The cable logging concept originated in Europe (Koroleff and Silversides 1949; Giordano 1959) but has been adapted to American conditions. In the vast Appalachian forests of 75 years ago, steam-powered cable systems supplanted the horse and ox as the primary method for skidding on steep land. During the first third of this century, the Lidgerwood (Fig. 2) skidders were the mainstay of timber harvest, yarding the old-growth timber from mountainsides to railroads (Fig. 3). Gove (1971) conveys some idea of the scale of those operations:

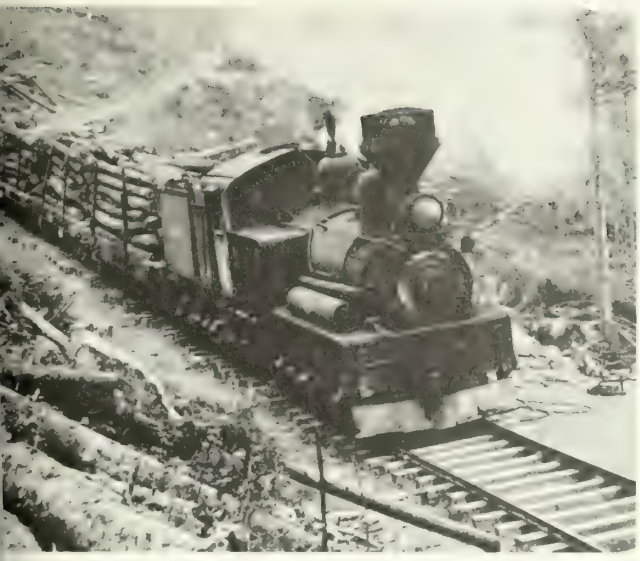
> An ideal setup location would allow the skidder to operate in a complete circle, reaching about 2,600 feet. The skyline was kept about 50 feet above the ground. Loaded, most of the weight was carried on the ground. Although skid trail damage usually was not severe, there were occasions when deep ruts would be gouged out near the yarding area. Some of these are still visible today. [Fig. 4]

Clarkson (1964) observed that the steam skidders "left behind a path of destruction that will scar our mountainsides for many years to come." On-the-ground examination of a 20-year-old steam skidder site (Fig. 5) in West Virginia suggested that as much as one-third of the soil had been severely disturbed, but the scars are virtually invisible beneath today's dense regrowth.

There are no known quantitative records that describe how forest streams were affected by soil disturbance of this magnitude. Many accounts, like this one by Brooks (1910), suggest substantial losses of water quality: "The natural water courses once were pure in all parts of West Virginia. Their drainage basins were covered with forests and farms, and the waters which fed the streams were clean. Many of these streams are sewers now."

Millions of acres were stripped of timber

**Figure 2.—High-lead logging with a Lidgerwood steam skidder. North Fork of the Gauley River, West Virginia, 1940.**



ure 3.—A loaded log train pulled by a Shay en-
e. Location and date unknown.

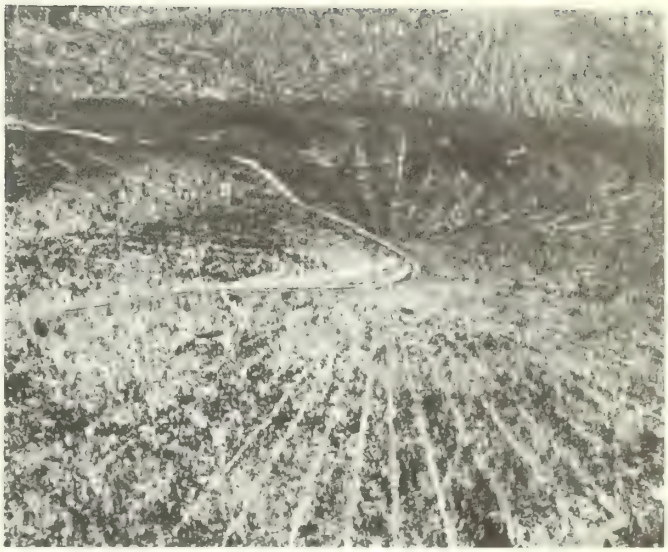
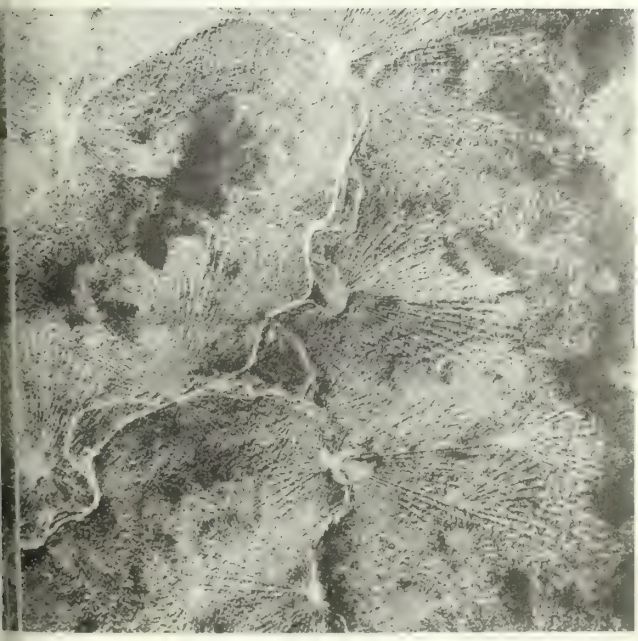


Figure 5.—Oblique aerial photograph of a radial pattern caused by steam skidding. Same vicinity as Figure 4 but taken in 1972. These patterns are invisible, lacking snow, because of dense, brushy revegetation.



gte 4.—Ground vegetation destroyed by
ea skidding (radial patterns). A logging
ilrad nearly bisects the aerial photograph.
iaer's Fork, West Virginia, 1945.

and further desolated by wildfire that so often followed logging (Fig. 6). The effects on visual appeal are obvious. Logging effects on most species of wildlife are not quantified, but there must have been large changes in animal populations. Deep concern about logging practices was not widespread (Simmons 1976). Presumably, much of the land so "improved" would be farmed. Much of it was, leading to a widespread form of subsistence agriculture on

Figure 6.—Logged and burned land near Davis, West Virginia, about 1930.

land better suited to producing wood and wildlife. These lands were prime targets for erosion control during the early years of the U.S. Soil Conservation Service; Barnes (1938) said, "The problems of soil use have arisen largely from attempts to farm land unfit for farming, and from failure to make provision for use of forest soil for forest production." To this day, the return of cutover land to forest production continues in the Eastern United States.

Even where agriculture was not a factor, damage to residual forest stands by steam skidders was cause for concern:

> On examining the areas logged by horses and that logged by steam skidders at the same period, it was found that reproduction was in better condition and more advanced where horses had been used. This is accounted for by the fact that in logging with skidders most of the reproduction is either uprooted or injured so that very little young growth remains after the operation. [Lacey 1920]

Despite general indifference to—indeed, even some support for—this despoliation of Appalachian forests, there was concern. Watson (1923), for example, deplored "The steam skidder and the methods of high-lead logging [that] are forest destroyers whose extraordinary destructiveness the forester cannot hope to overcome." Eventually, the problem solved itself because the need for large-scale harvest methods disappeared as the old-growth forest disappeared. Until that time, neither the forests nor the technology were well suited to harvest methods other than clearcutting and yarding with steam skidders.

Foresters preferring harvest methods other than clearcutting deplored the steam skidder. "Skidding by overhead or ground cables would be ruinous to trees left and to advance reproduction. Partial cutting obviously is best suited to logging by animals rather than by machines" (Frothingham 1931). But even logging with animals was not without environmental damage (Fig. 7), as shown by this account of a horse logging job in New Hampshire:

> I mapped a portion of it in detail and found that 60 percent of the area was in skid trails and landings, or covered by deep windrows of logging slash. Almost every residual tree was knocked down or skinned up, and the advance reproduction was almost completely eliminated. [Simmons 1957]

The conditions characterized by this era continued over much of the Appalachian region until World War II.

The destruction that characterized turn-of-the-century logging is unlikely to recur. The harvest techniques of that era, either machine

**Figure 7.—A horse logging job near St. George, West Virginia, about 1965.**

or animal, no longer are used. More important, timber is harvested today long before it can attain the size of old growth. And loggers are learning to protect the land. Smaller timber, improved harvest techniques, and concern by loggers as well as the public, virtually precludes the environmental ruin reminiscent of the steam skidder in its heyday (Hawley and Smith 1954).

## THE POST-WORLD WAR II ERA

By 1950, little remained of the old-growth forest in the Appalachian region. But despite some grim after effects of earlier logging, most of the cutover land had regenerated to thrifty stands of second-growth hardwoods. All of society's need for goods and services from the eastern forest would be met from these new stands. The transition to new conditions in the logging industry in the Northeast was summarized by Simmons (1977):

> Following World War II the revolution in logging methods and equipment took place. Egged on by a diminishing labor force, that demanded higher pay and easier jobs, logging operators were avidly seeking more efficient ways of doing the job. Equipment manufacturers with excess capacity due to cancellation of wartime contracts, but with many new ideas and techniques developed during the war, were quick to respond. The old two-man chainsaws, weighing upward of 100 pounds, were whittled down by stages to efficient one-man models. The crawler tractor was made a more efficient skidding machine with the addition of winches and arches. Then, in the early 50's, the rubber tired skidder was developed. . . . Motor trucks were improved, made sturdy and efficient, and log loaders were progressively improved. . . . These developments continue to the present day.

A similar transition occurred in the Southeast. There, interest in avoiding some of the environmental problems associated with logging centered at the Coweeta Hydrologic Laboratory:

> A considerable change has taken place in the last 9 years in logging methods and uses for forest products in the southern Appalachian Mountains. In 1942, when the Coweeta study of poor logging methods started, the common method of skidding was with oxen and horses. After World War II the emphasis changed from animal to power equipment appearing in the woods. After being considered an uneconomical method for 25 years, the high-lead logging system reappeared this quarter and demonstrated that it will have a place along with other power logging equipment in the southern Appalachians. At present the high-lead system is being used on a job near Highlands, North Carolina, to remove high quality logs from narow valleys with steep slopes and small coves or benches which have heretofore been considered inaccessible.[1]

**Figure 8.—Wyssen skyline system operating in the Cullasaja River drainage, near Franklin, North Carolina, about 1950.**

The power logging equipment referred to was not a high-lead system; it was the Wyssen skyline (Fig. 8), and would be tested throughout the United States during the decade to follow. In tests from the Atlantic to the Pacific, in New York and Canada (Fobes 1950), the Rocky Mountains (Matson 1956), Washington (Wooldridge 1960), and Alaska (Weisgerber 1962) the findings were unanimous; the Wyssen caused little soil disturbance and no evidence of accelerated soil erosion. Herman (1960) provided the most complete account of this:

> Soil disturbance was negligible on both clear-cut and selection-cut areas. Defined skid trails

[1]Unpublished quarterly report of Oct-Dec 1951. Division of Forest Influences Research, Southeastern Forest Experiment Station, Asheville, North Carolina.

**Figure 9.—An A-frame skidder loading a logging truck in Georgia, 1957.**

are inconspicuous on completed settings. They are not continuous and are scattered so that water concentrations do not occur. The only evidence of exposed soil was confined to a few narrow short stretches. These were found only at points where the skyline was low and slope configuration was convex. No stretches of exposed soil exceeded 20 feet in length. These observations coincide with those made on other skyline-crane logging test areas . . .

The equipment performed well when used in selectively cut dense timber. Damage to the dense residual stand, even where logs were skidded more than 150 feet, was light.

E. A. Johnson[2] expressed a counteropinion that the Wyssen system caused two or three times more damage to residual hardwood trees than did timber harvest systems then used in North Carolina.

[2]Personal communication. U.S. Forest Service Headquarters, Washington, D.C.

Present interest in cable logging as a means to protect environmental values probably stems from those tests. Minor damage to forest trees, soil, and water had been clearly demonstrated. But much adaptation of the Wyssen system was needed before its assets in terms of environmental protection could override its economic liabilities; to this day, operational costs bar its acceptance as a viable alternative for harvesting wood products under Appalachian conditions.

The concept, nevertheless, had taken root and attempts to adapt cable logging equipment to hardwood forest conditions seem nearly as limitless as human ingenuity. The simplest was the A-frame (Fig. 9). But this and similar devices often became "dead ends," unacceptable to loggers because they were

poorly adapted to local conditions or because they soon became obsolete. To date, the common stumbling block of all adaptations is their inability to skid logs as cheaply as competitive systems. A complete list of cable logging devices will not be attempted, but the following examples illustrate continuing interest in applying the cable concept.

Some devices (Koreloff and Silversides 1949; Church 1972) have tried to put gravity to work. Adaptations of western logging machinery—the jammer (Bond 1959), high-lead (Pulpwood Production/Timber Harvesting 1976), skyline (Fobes 1947), tractor (Northeastern Logger 1953), and helicopter (Perkins 1963)—have applied the cable concept under eastern conditions with limited success. Cable skidding bundles of small products has been tried from Alabama (Cline 1956) to Canada (Seheult 1955). Even miniature equipment has been tried for cable skidding small products (Taylor and Richardson 1963). A new application of the skyline principle is being developed at Purdue University (Perkins 1975). Recently, sophisticated western (Pulpwood Production and Sawmill Logging 1973; Priegel 1975), European (Wendel et al. 1974), and aerial (Welsch and Abplanalp 1977) equipment has been tested in the Appalachians (Fig. 10). To date, none of these devices seems uniquely adapted to hardwood logging conditions and none is economically competitive with conventional logging systems.

**Figure 10.—Skylok skyline system yarding whole trees to a chipper. Gauley Woodlands, West Virginia, 1977.**

## Environmental effects

Only the effects of cable logging on soil, water, residual stands, wildlife, and visual appeal are considered in this paper. "Environment" is, of course, broader than these parameters but the effects of cable logging on air quality, energy consumption, noise, etc. have received so little attention that no discussion of them is undertaken.

For many years, the forestry profession has been aware of the need to better protect our forest environment:

> Concern for the quality of man's environment is one of the most potent forces in this highly urbanized society. Public concern often is evident in the whole field of natural resources, but it is sharply focussed on management of forest land, and particularly on publicly owned land. . . . It is imperative that forest land be managed to minimize impacts on soil, water, air, wildlife, and esthetic values. [Resler and Buckman 1973]

Experience suggests that cable logging is a promising means to minimize the environmental impacts of wood products harvest on forested land in the mountainous East.

*Effects on soil.* Packer's (1967) review established that logging roads are primary sources of eroded soil in the managed forest. A logging road is defined as any prepared travel route whereon mineral soil has been exposed and compacted by human use (Fig. 11).

Burke (1975) maintained that improperly located and constructed timber access roads and landings cause the greatest adverse impact of all activities relating to timber harvest (Fig. 12). Frothingham (1931) recognized

Figure 11.—Removal of the organic cover from logging roads exposes the underlying soil to accelerated erosion. Soil compaction and rutting by machinery worsen erosion.

Figure 12.—Carelessly built logging road and landing located too close to a stream. Here, eroded soil quickly becomes stream sediment. Location and date unknown.

**Figure 13.—Several cubic feet of soil were eroded per lineal foot of this carelessly built and managed logging road. Near Franklin, North Carolina, 1952.**

that there was little danger of serious erosion from tree cutting on unburned land, pointing instead to deeply worn skid trails as the greater threat (Fig. 13). The same thought was expressed by Kidd and Kochenderfer (1973); nevertheless, the role of roads as prime erosion sites in forests finds only grudging acceptance within the logging fraternity and is often unrecognized. This lack of acceptance seems strange because logging roads are everywhere in the eastern forest; Lull and Reinhart (1965) estimated 1,620 miles in the upper Potomac River Basin alone. Pruett (1975) estimated that 3 to 7 percent of the total forest area may be in roads. Kochenderfer (1977) measured from 6 to 16 percent of the soil bared by roads on more than 1,000 acres of freshly logged land in West Virginia. Dissmeyer (1976) estimated even more, up to 25 percent, bared by logging on mountainous land. Methods to control soil erosion on such roads are well known (Kochenderfer 1970) but too often are not applied.

Walbridge (1960) proposed the use of self-propelled cable skidders in Tennessee as "about the only means of mechanizing skidding in terrain exceeding 35 percent slopes other than riddling the area with skidding roads." Experience substantiates this assertion in the West as well as the East, although careful planning also reduces area in logging roads (Mitchell and Trimble 1959). Burke

**Figure 14.—Soil disturbance accompanying modern skyline harvest on the Gauley Woodlands. The forest litter has been mixed with surface soil but there has been no evidence of accelerated erosion. West Virginia, 1977.**

(1975) stated that "a well-planned running skyline system can substantially reduce access road mileage" by perhaps one-third of the roads built during high-lead logging (Binkley 1965). Limited eastern experience bears out that these reductions are possible; Kochenderfer and Wendel (1978) report less roads where cable systems were used:

| *Skidding system* | *Acres served per mile of road* |
|---|---|
| Wheeled skidder | 20 |
| Jammer | 31 |
| Skyline | 80 |

Thorsen[3] found that 5 acres of land in roads served 117 acres of land logged with a high-lead system in Georgia, about 1 mile of road per 40 acres of land. In West Virginia, cable logging required fewer roads than tractor harvest, with the only required road on a ridge top above each cutting unit.[4] Megahan and Kidd (1972) lucidly expressed the environmental benefits of fewer logging roads, their western experience being fully applicable to eastern conditions:

> Jammer logging in the past has required a dense network of roads with a maximum road spacing of about 400 feet. In steep country this may disturb soil on 25 percent of the total logging area. Skyline logging systems permit road spacing up to 1,600 feet or more, depending on the local conditions. This reduces the area dis-

[3]James Thorsen. Unpublished report on file at the Tocoa District Headquarters, Chattahoochie National Forest, Tocoa, Georgia.

[4]Personal communication from Dr. Bruce Brenneman, WESTVACO, Rupert, West Virginia.

turbed by perhaps 75 percent and may provide a greater buffer area for sediment deposition between the roads and the stream channel. Thus, by far the greatest benefit to be derived from skyline logging systems with respect to erosion reduction results from reduced road mileage.

Logging, even by cable systems (Fig. 14), also disturbs the soil on nonroaded forest land. These effects have been evaluated many times in the West. Ruth (1967), for example, reported 15.8 percent of the mineral soil exposed by high-lead systems, only 6.4 percent by skylines. Logging with a tractor disturbed much more soil than did a skyline, with 36.2 percent as opposed to 2.8 percent severely disturbed (Klock 1975). Soil disturbance by tractor may be almost three times greater when slopes exceed 40 percent (Garrison and Rummell 1951). The effects of logging on western soils were cogently summarized by Swanston and Dyrness (1973):

| *Method* | *Bare soil (%)* | *Compacted (%)* |
|---|---|---|
| Tractor | 35.1 | 26.4 |
| High-lead | 14.8 | 9.1 |
| Skyline | 12.1 | 3.4 |
| Balloon | 6.0 | 1.7 |

There are many claims of minimal soil disturbance by cable systems in the East, but few precise reports. Ponder,[5] Aydelott et al.,[6] Douglass,[7] and Knight (1976) were impressed with the lack of disturbance to mineral soil during and after jammer logging in the southeast (Fig. 15). In Georgia, McCoy[8] reported 10 to 15 percent of the soil disturbed by high-lead logging on transects chosen as most disturbed on the cutting unit. For the entire cutting unit, less than 6 percent of the soil was disturbed.[9] Prater (1973) reported so little soil damage (in Louisiana) that not even the most avid environmentalist was disturbed. Such glowing, though unquantified, evaluations attract interest but provide little concrete basis for comparing soil disturbance among logging systems.

**Figure 15.—Note the lack of soil disturbance after skidding with a tractor and cable system. South Carolina, 1957.**

Dickerson (1968) made these comparisons in Mississippi:

| *Logging methods* | *Soil area disturbed (%)* |
|---|---|
| Rubber-tired skidder | 17 |
| Crawler tractor | 14 |
| Mule | 12 |
| A-frame (a cable system) | 12 |

After use of a skyline in West Virginia (Fig. 16), Patric and Gorman (1977) observed no change in bulk density of $B_2$ horizon soil (Fig. 17), no decrease of infiltration rates, and no evidence of accelerated soil erosion. These results pertain to logged land, not to roads or skid trails. The authors reported the following degrees of soil disturbance:

[5]Felix Ponder, Jr. Typewritten report of erosion plot check on file at Jefferson National Forest Headquarters, Roanoke, Virginia.

[6]D. Gray Aydelott and Thomas E. Elson. Typewritten evaluation of cable logging demonstration on file at Jefferson National Forest Headquarters, Roanoke, Virginia.

[7]Personal communication from James E. Douglass, Coweeta Hydrologic Laboratory, Franklin, North Carolina, Feb. 11, 1974.

[8]Personal communication from William J. McCoy, Soil and Watershed Staff Officer, Chattahoochee National Forest, Gainesville, Georgia.

[9]Personal communication from Earl Priegel, U.S. Forest Service, Atlanta, Ga.

**Figure 16.—The URUS, a small European skyline system tested near Parsons, West Virginia, 1976-1977.**

| *Degree* | *Percent of area* |
|---|---|
| Severe (B horizon exposed including roads and skid trails) | 2.9 |
| Slight (A horizon exposed) | 6.8 |
| None (No more than litter rearrangement) | 90.3 |

Perhaps the most thoroughly documented report on soil damages caused by logging was from New York (Craul 1976). There, increased bulk density on skid trails decreased macroporosity, water availability, and infiltration (Fig. 18). It was estimated that these changes increased the erosion potential 0.024 ton per acre of logged land, increasing by 50 percent the erosion rate for forest land reported by Patric (1976). Lull's (1959) review of the compaction literature suggests that the increased bulk density observed by Craul (1976) is a relatively short-lived phenomenon. Reinhart (1964), too, showed that reduced infiltration was restricted to skid roads in West Virginia.

Figure 17.—Note typical lack of disturbance to subsoil beneath a lightly used skid trail about 4 months after logging, near Franklin, North Carolina, 1952.

Figure 18.—Note lack of surface disturbance during cable skidding by tractor. Somerset County, New Jersey, 1954.

*Effects on water.* Packer's (1967) review established that it was not the cutting of trees but the method of logging, primarily road practices, that increases sediment in streams draining logged land. Bates (1924) had recognized this problem nearly half a century earlier:

> Any road, built with ordinary care and provision for drainage, and traversing a section of mountain forest land, will have and does have a greater effect on streamflow as measured in terms of erosion, than would the cutting of the entire section of timber, or its burning, provided the burned or cut area was not afterward disturbed.

Reinhart's (1975) statement was even broader:

> . . . we have for the Appalachian Highlands the most complete and detailed information available anywhere on the response of streams to management of their watersheds by man . . . Research and general observation have amply demonstrated that it is not the cutting of trees, but the baring and compaction of mineral soil incident to removal of products that caused major erosion and sediment damage. This observation may seem simple and self-evident, but it is often ignored in present-day arguments about forest practices.

There is ample evidence to support the contention that wood products can be harvested by conventional (i.e., noncable) methods, on good roads, without ill-effects to water (Northeast. For. Exp. Stn. 1975). If this is possible with conventional systems, it is almost certain that ill-effects will not be caused by cable logging. Unfortunately, most of the supportive evidence is not quantitative.

With erosion controls conscientiously applied, cable logging was reported to cause little apparent change in water quality in Georgia (Black and Clark 1958; Aydelott et al.),[6] in North Carolina (Vogenberger and Curry 1959), in Virginia (Virginia Division of Forestry 1955), and in Pennsylvania (Heagy 1960). Perhaps nowhere have the methods needed to protect water quality been described more concisely than by Walker:[10]

> Prior to logging, a series of contour secondary roads were punched in by the contractor under Coweeta personnel supervision. Grades of 3 to 5 percent with short pitches were maintained. Long dips of 30 to 50 feet at stream crossings provided water diversions. Closed culverts were installed at streams. Logging was done uphill to a haul road with an A-frame power skidder. Maintenance was performed daily to keep structures open. Following the logging of a section of haul road, deeper water diversions were constructed and oats, rye, or rye grass planted. Fertilization accompanied seeding. Even though rainfall was 7 inches above normal during logging, damage to water quality was negligible.

Stream turbidity on the watersheds studied by Walker differed little from that on permanently forested watersheds.[11] Several years later, the logging roads were grass covered and some trees were growing on them. Skid trails caused by A-frame logging (Fig. 19) were barely visible. In short, there was no evidence of accelerated soil erosion or of reduced water quality.

The road practices described by Walker[10] were applied on a larger scale several years later in North Carolina (Hewlett and Douglass 1968). Sediment production was increased temporarily by about 50 percent, an effect attributed to attempts to "improve" the trout habitat. On this watershed, logs were winched to tractors, a form of ground skidding developed for reaching between roads and into hard-to-get-at places (Northeastern Logger 1953).

Just one of many reports is cited to show how careless logging can damage water quality (Delaware Basin Research Center):[12]

> The site was on a steep mountainside and covered a large area with a light cut per acre. Skidding was done during the past winter and spring by tractor, with skid trails generally running perpendicular to the contours. No attempt was made to avoid water courses and, as a result, flowing water got into the tractor ruts. Erosion was accelerated by the running water until the ruts are now 3 to 4 feet deep in places. These eroding ruts appear to have taken the place of original stream channels. Thus a source of erosion and sedimentation has been developed which may take a number of years to be corrected by nature.

Western experience closely parallels that for the East. There, too, the impact of logging activities on water quality is determined largely by the extent to which a forested area is disturbed by the network of access roads

[10]Laurence C. Walker. Typewritten report on file at the Coweeta Hydrologic Laboratory, Franklin, North Carolina, 43 p.

[11]Laurence C. Walker. Typewritten graduate report for University of Georgia. On file at the Coweeta Hydrologic Laboratory, Franklin, North Carolina, 43 p.

[12]I. C. Reigner. Unpublished quarterly report for August 1950. Division of Forest Influences Research, Northeastern Forest Experiment Station, Broomall, Pennsylvania.

**Figure 19.—A-frame yarding logs on steep mountains near Franklin, North Carolina, 1952. Both A-frame sites and skid paths were fully revegetated and could not be traced by 1960.**

and by the movement of logs from stump to landing. The U.S. Environmental Protection Agency (1976) published a massive review of the pertinent literature; of the several cable systems, skylines in general least affect the site and, presumably, water quality.

East or West, the principles for maintaining clear streams, during and after logging, are deceptively simple. (a) As nearly as possible, maintain an unbroken litter cover (Fig. 20). Although logging residues are ugly (Fig. 21), they actually reinforce the litter cover and its erosion control function. (b) Build the fewest roads possible, design and maintain them correctly, and pull logs to roads (Fig. 22) by cable methods. (c) Stabilize eroding roads with brush (Fig. 23) or grass, a particularly important measure where eroded soil can quickly be transformed to stream sediment (Fig. 24). (d) Since litter-covered forest soil erodes very slightly, stream channels are the major source of sediment on most eastern forest land (Fig. 25). Logging machinery must be kept out of channels, even on tiny tributary streams (Fig. 26), if dirty water is to be avoided.

Although there is abundant evidence that tree cutting greatly influences the quantity as well as the timing of streamflow (Northeast. For. Exp. Stn. 1975), there is no evidence that methods of logging influence these properties of forest streamflow.

Figure 20.—An unbroken litter cover on the forest floor almost always prevents accelerated erosion of soil. The littler cover absorbs the entire kinetic energy of falling rain and facilitates the infiltration of rain as fast as it falls. Illinois, 1930.

Figure 21.—Logging residues are unsight but add greatly to the soil-protective functi of the forest floor. Michigan, 1957.

Figure 22.—Winching logs to a tractor. Note minimal disturbance to the forest floor. Illinois, 1953.

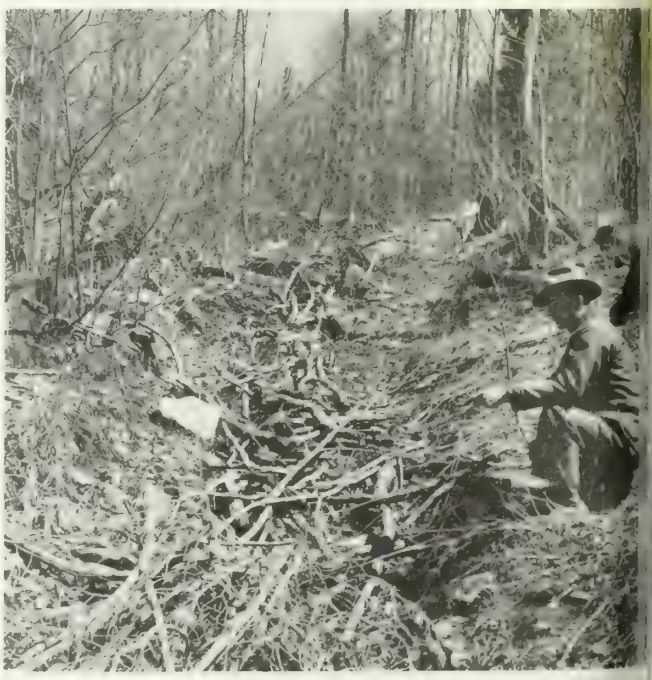


Figure 23.—This entrenched logging road has been packed with logging debris to control further soil erosion. North Carolina, 1950.

Patric, James H.
1980. **Some environmental effects of cable logging in the Appalachian forests.** Northeast. For. Exp. Stn., Broomall, Pa.
29 p., illus. (USDA For. Serv. Gen. Tech. Rep. NE-55)

The forestry literature was reviewed for reports concerning effects of wood products harvest on forest soil, water, residual stands, wildlife, and visual appeal. In all cases, cable logging caused less unwanted effect on all of these resources than did other harvest systems. Even though the concept of cable logging is well established, logging machinery built according to this principle, that is fully suited to harvesting the eastern hardwood forest, has not been developed.

116.28, 907.3

**Keywords:** Hardwood forests, highlead logging, horse logging, residual stand damage, soil, tractor logging, visual appeal, wildlife

Patric, James H.
1980. **Some environmental effects of cable logging in the Appalachian forests.** Northeast. For. Exp. Stn., Broomall, Pa.
29 p., illus. (USDA For. Serv. Gen. Tech. Rep. NE-55)

The forestry literature was reviewed for reports concerning effects of wood products harvest on forest soil, water, residual stands, wildlife, and visual appeal. In all cases, cable logging caused less unwanted effect on all of these resources than did other harvest systems. Even though the concept of cable logging is well established, logging machinery built according to this principle, that is fully suited to harvesting the eastern hardwood forest, has not been developed.

116.28, 907.3

**Keywords:** Hardwood forests, highlead logging, horse logging, residual stand damage, soil, tractor logging, visual appeal, wildlife

Patric, James H.
1980. **Some environmental effects of cable logging in the Appalachian forests.** Northeast. For. Exp. Stn., Broomall, Pa.
29 p., illus. (USDA For. Serv. Gen. Tech. Rep. NE-55)

The forestry literature was reviewed for reports concerning effects of wood products harvest on forest soil, water, residual stands, wildlife, and visual appeal. In all cases, cable logging caused less unwanted effect on all of these resources than did other harvest systems. Even though the concept of cable logging is well established, logging machinery built according to this principle, that is fully suited to harvesting the eastern hardwood forest, has not been developed.

116.28, 907.3

**Keywords:** Hardwood forests, highlead logging, horse logging, residual stand damage, soil, tractor logging, visual appeal, wildlife

Patric, James H.
1980. **Some environmental effects of cable logging in the Appalachian forests.** Northeast. For. Exp. Stn., Broomall, Pa.
29 p., illus. (USDA For. Serv. Gen. Tech. Rep. NE-55)

The forestry literature was reviewed for reports concerning effects of wood products harvest on forest soil, water, residual stands, wildlife, and visual appeal. In all cases, cable logging caused less unwanted effect on all of these resources than did other harvest systems. Even though the concept of cable logging is well established, logging machinery built according to this principle, that is fully suited to harvesting the eastern hardwood forest, has not been developed.

116.28, 907.3

**Keywords:** Hardwood forests, highlead logging, horse logging, residual stand damage, soil, tractor logging, visual appeal, wildlife

*Residual stand damage.* Long ago, Lacey (1920) concluded that:

> . . . any system of logging is bound to destroy much of the reproduction. It is, therefore, a matter of using the less destructive means. On examining the area logged by horses [parallel skid trail patterns near the center of Fig. 27] and that logged by steam skidders [radial skid trail patterns, Fig. 27], it was found that reproduction was in far better condition and far more advanced where horses had been used.

But lest horse logging be held blameless in residual stand damage (Fig. 28), consider this observation by Simmons (1957):

> . . . in West Virginia . . . we tried to establish some permanent camera points which would show residual stands following logging of which we were particularly proud. At almost every one of these points the good residual trees were destroyed or damaged by the horse loggers, usually because they were in the way of a skid trail or a landing area.

Westveld (1926) too, reported 18 to 20 percent damage after horse logging in New Hampshire. Despite such observations, Frothingham (1931) concluded that "greatest destruction occurs when cable skidding is done with powerful, stationary donkey engines." Simmons (1959), on the other hand, found that the volume and number of trees damaged, regardless of care in logging, was about the same with all methods.

The effect of care in logging is clearly evident in data from the South. There, loblolly pine was prized more than hardwood and was logged more carefully (McKinney 1934):

| | *Old field* | | *Forest grown* | |
|---|---|---|---|---|
| | *Pine* | *Hardwood* | *Pine* | *Hardwood* |
| Residual stand damage (%) | 12 | 35 | 19 | 39 |

With the development of smaller and more mobile skidders, ruinous damage to residual trees was no longer an accepted fact.[13] Mechanized thinning by several methods used in the Lake States caused similar numbers of injuries (Biltonen et al. 1976). When reasonable precautions were taken to minimize injury during selection logging in the Central States, less than 10 percent of the residual stands were damaged (Deitschmann and Herrick 1957).

[13]Logging specialist, Joseph H. Smith, Northeastern Area, U.S. Forest Service, Morgantown, West Virginia.

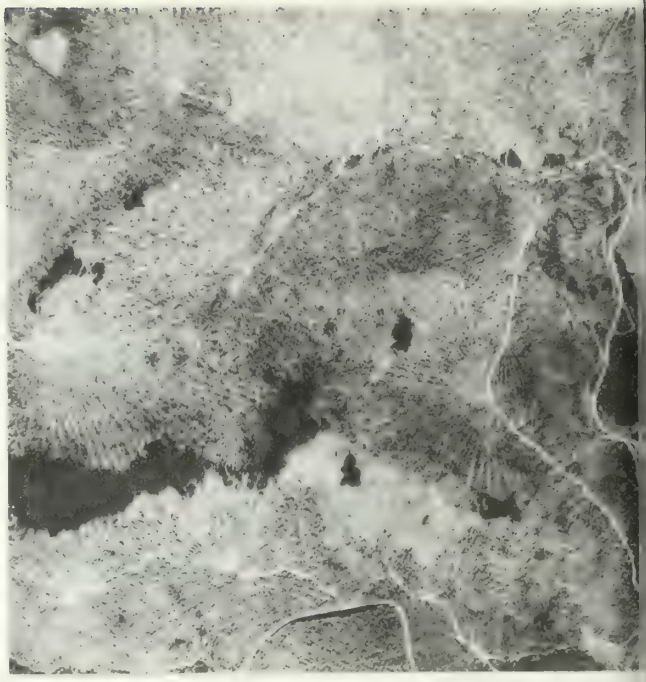


**Figure 27.—Aerial view; skidding patterns caused by horses (center of photo) and steam skidders (radial patterns). Shaver's Fork, West Virginia, 1945.**

**Figure 28.—Tree injury caused by cable abrasion or impact of skidding log. North Carolina, 1955.**

But in Virginia, large tractors caused less damage than small tractors (King 1963). Injury was similar for wheeled skidders and crawler tractors in New York (Nyland and Gabriel 1972). Damage caused by tractors differed little from that caused by horses in the Lake States (Perkins 1969). These highly variable evaluations probably bear out the truth of Simmons' (1957) conclusion that lack of planning and careless practices can cause excessive damage by any harvest system.

The felling crew can do much to avoid skidding injury (Herrick and Deitschman 1956), a fact also noted by Wendel and Kochenderfer (1978). Herrick and Deitschman (1956) concluded that less than 10 percent of the residual trees, and these mostly saplings (Meyer et al. 1966), should be damaged by logging operations conducted with reasonable care.

Residual stand damage is held to low levels with cable systems. Only 7 percent of the residual trees (34 per acre) sustained yarding injury during skyline logging in West Virginia (Wendel and Kochenderfer 1978). Aulerich et al. (1974) found nearly the same number of wounded trees after tractor and skyline thinning in Douglas-fir, but Lysons and Twito (1973) reported little stand damage by skyline systems in partial cuts.

*Wildlife.* The abundance of animal life in forests is directly related to energy gradient. In most forests, the availability of solar energy decreases with crown depth until little is available on the forest floor. Animal species are adapted to meet their energy needs at rather specific levels within this distributive system (Webb 1973). Deer browse from the branches of younger trees and brush. Wild turkey, small game, and songbirds seek sunlight at various levels for warmth, nesting areas, and food (Fig. 29). In areas where forests are managed to meet these energy needs, wildlife populations have increased in nearly every instance (Miller 1973).

Because many animal species are specialized to rather rigidly defined energy strata (Fig. 30), diversity among species tends to be higher where energy distribution is most diverse. Therefore, it is tree cutting and not the logging system that is of paramount significance to wildlife. To paraphrase Wing (1951),

**Figure 29.—Raccoon in hollow tree. Tree-denning animals require large, old trees. Vermont, 1962.**

**Figure 30.—Ring-neck pheasant. Wildlife that live and feed on the ground or in openings cannot thrive in dense stands of large and mature trees. West Virginia, 1929.**

it is not so much a matter of what is cut or how it is logged, as how much is cut and where. The effects of cutting on wildlife tend to vary with scale of cutting relative to size of home range among the animals of interest.[14] Of all the cutting methods, group selection (Minckler 1975) provides the scale of cutting of greatest value to wildlife (Fig. 31). Roads, too, benefit wildlife by providing diversity of food and cover (Fig. 32), as do openings created by logging. Openings made by logging roads also tend to distribute energy diversely from the tree canopy to the forest floor.

Group selection is a logical harvest method for small scale operations (Minckler 1975), but it becomes inappropriate when there is a large investment in expensive cable logging systems.[14] WESTVACO, for example, clearcuts 40-acre blocks in West Virginia (Parker 1976) in order to operate their large machines efficiently (Fig. 33). Thus, wildlife management is linked to economics, with group selection a logical choice on small forest properties, but an awkward and expensive alternative on large holdings. Probably only the smallest, most mobile, and least costly of the cable systems will find economic use as a group selection harvest method.

Cable logging effects on soil and water have clear implications for fish. Any logging system that materially increases sediment in streams can injure fish populations. Since cable logging has the least effect on soil erosion and stream sedimentation of all harvest systems, presumably it is the least injurious to fish. No literature was found that bears directly on how cable logging affects fish.

*Visual appeal.* The pleasure that people derive from all of their senses is strongly conditioned by their expectations.[15] Thus, to most urban people, the aftermath of logging appears untidy and generally destructive (Fig. 34). People closer to the land view logging more tolerantly, but even they consider it a necessary evil unlikely to improve a forest

**Figure 31.—Wood products harvest by group se tion creates many forest openings, usually less t ½ acre. These small openings leave large amo of the forest edge so favored by wildlife. Michi 1962.**

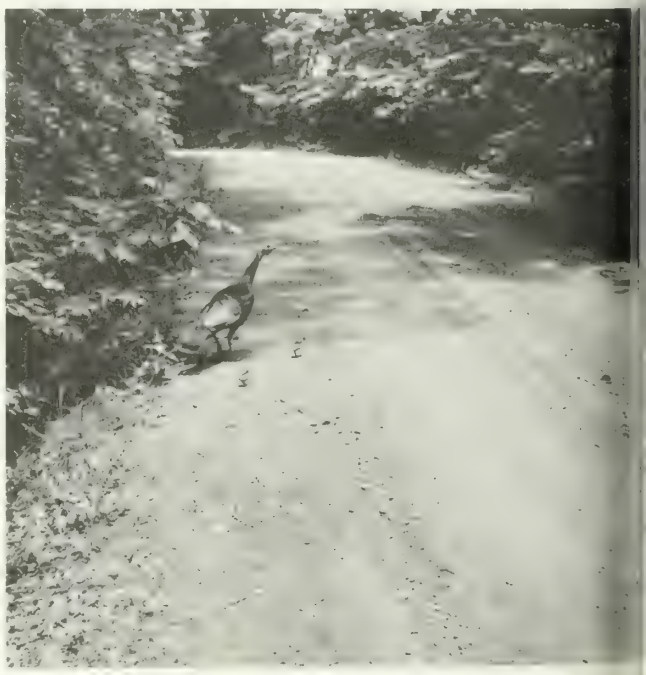


**Figure 32.—Well-kept logging roads, too, provide large amounts of forest edge. Virginia, 1965.**

[14]Personal communication from John D. Gill, Wildlife Biologist, U.S. Forest Service, Morgantown, West Virginia.

[15]E. M. Gould, Jr. Unpublished report, Harvard University, Harvard Forest, Petersham, Massachusetts. 43 p.

**Figure 33.—On the Gauley Woodlands, whole trees are chipped into vans and trucked to a paper mill. West Virginia, 1977.**

**Figure 34.—High-grading leaves inferior trees for the new crop and wasted wood. Visual appeal is minimal but slash enhances the soil protective role of the forest floor. New York, 1938.**

landscape. Some critics even believe that "sawlog forestry" destroys the beauty of a countryside and should be stopped. A more moderate approach places esthetic value on a par with timber, water, wildlife, and other longer recognized values of the forest (Gainer and Lohr 1970). It is public expectation of visual pleasure in the forests, and public experience of visual displeasure, that has placed the forestry profession squarely on the hot seat of controversy:

> Most of the criticisms of forest cutting practices that have been voiced in recent years have been aimed specifically at clearcutting, and boil down to displeasure with the appearance of fresh clearcut areas. Attempts to minimize slash and soil disturbance, limits on the size openings and their proximity to older ones have helped some, but clearcuts remain unpleasant sights for many forest users. [Marquis 1977]

In dealing with the problems of timber production and landscape amenity, Gould[15] conceived of the "misfit" as any deleterious situation detracting from the forest's visual appeal. Gould's definition of misfits is more easily

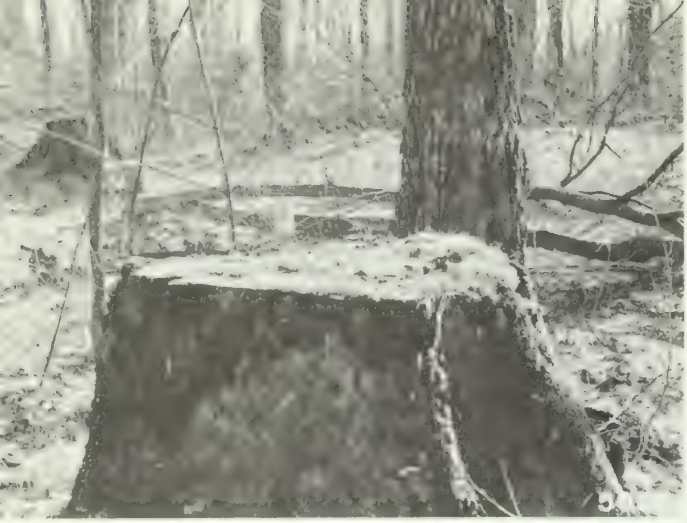


**Figure 35.—Stumps, unutilized trees, and logging slash are visual misfits in this selectively harvested forest. Michigan, 1960.**

**Figure 36.—A well-cared-for opening has great visual appeal and offers easier travel than the surrounding forest. Michigan, 1956.**

grasped than is the usual nebulous application of esthetic theory to a forest setting. Briefly, misfits are disorganizations in the usual forms of forest materials, or they are physical obstacles to traversing and viewing the forest (Fig. 35).

To some extent, this definition of misfits supports the notion that beauty is in the eye of the beholder. Nevertheless, it is possible to make certain generalizations about misfits and visual appeal. Most observers prefer least disturbance in forests (Wilhite and Sise 1974). Openings add visual appeal (Fig. 36), although they should be tailored to their locale (Brush 1976). Variety (Fig. 37) is a major criterion of visual appeal (Cook 1972). Partial cuts (Fig. 38) usually are preferred to clearcuts (Echelberger 1976). In one survey, recreationists preferred cut and uncut stands almost equally, a departure from the usual choice of uncut stands (Shafer 1969). Visual landscape harmony is reduced by patterns of timber harvest and by overly obtrusive logging roads (Trimble et al. 1974). The list of such study results might extend almost indefinitely. It seems long enough, however, to suggest that the dearth of misfits that follows carefully controlled cable logging can help foresters meet the visual expectations of many people (Fig. 39). Others, too, have tried to list misfits, then evaluate the capability of logging systems to achieve selected characteristics. Excerpts from one such summary[16] reflect the subjectivity of any visual evaluation:

**Figure 37.—Even a well-kept logging road offers scenic relief from the unbroken forest. Virginia 1955.**

[16]Unpublished report furnished by Dr. David Marquis, U.S. Forest Service, Warren, Pennsylvania, 186 p.

| Desired visual characteristic | Logging system | | | | | | |
|---|---|---|---|---|---|---|---|
| | Horse | Wheeled skidder | Crawler tractor | Jammer | High lead | Sky-line | Heli-copter |
| Low road density | 1 | 2 | 2 | 1 | 2 | 3 | 3 |
| Small landings | 3 | 2 | 2 | 2 | 2 | 2 | 1 |
| Flexibility for feathering edges and leaving islands | 3 | 2 | 2 | 2 | 1 | 3 | 3 |
| Flexibility for shaping clearcuts | 3 | 3 | 3 | 2 | 2 | 3 | 3 |
| Capability for small clearcuts | 3 | 3 | 3 | 2 | 2 | 2 | 3 |
| Low damage to residual trees | 3 | 2 | 2 | 2 | 1 | 2 | 3 |
| Low surface disturbance | 3 | 1 | 1 | 1 | 1 | 2 | 3 |

Scale: 3—most compatible; 2—moderately compatible; 1—least compatible.

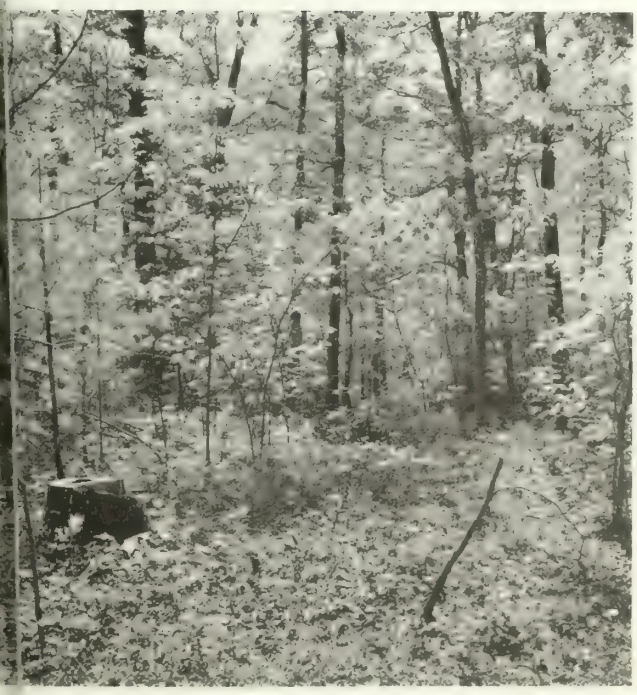


**Figure 38.—Removal of an occasional large tree maintains the forest character of land harvested by selection systems. Virginia, 1942.**

Apparently the authors were unaware either of the destructive potential of horse logging or that jammer logging—from an environmental standpoint—represents a considerable advance over systems currently used in the Eastern United States.[17]

Cable logging shows promise in forest land management where visual appeal is important. Is this not implied in the following quotation?

> Multiple-use management, or more specifically, timber-aesthetics management of forest stands for timber production and dispersed wildland recreation activities requires a knowledge of the kind of stand that will best serve the recreation purpose of the area and the silviculture skill to maintain or modify the stand for both timber and aesthetics. In this respect, one of the most important objectives of timber aesthetics management is to shorten the post-logging period during which most types of recreational activities, except hunting, are usually restricted. [Shafer 1967]

[17]Kochenderfer, James N., and G. W. Wendel. Costs and environmental impacts of harvesting timber in Appalachia with a truck-mounted crane. [In process]

Figure 39.—Skyline logging near Parsons, West Virginia, 1977. In summer (a) observers are unaware that the ridge in the background was heavily harvested. Only with snow on the ground (b) are the skyline paths visible.

## DISCUSSION

The past decade or two has witnessed a significant shift in the goals of many Americans with respect to forest land management: The production of wealth is no longer the primary goal. For better or worse, the safeguarding of amenity values (e.g., clean water, abundant wildlife, visual appeal) is often held above production of wealth. Thus, much thought and planning are directed to lessening the impact of wood products harvest on environmental values of the forest.

On perhaps our largest scale of planning, the Forest Service's Multiple Use Advisory Committee calls for greater emphasis on esthetics and landscape architecture during wood products harvest on the National Forests (USDA 1976). Clearcutting in small patches and avoiding destruction of ground cover are among management measures recommended. This Committee also recommends that Forest Service research develop new knowledge of soil and water resources, and that problems hindering effective management of these resources be solved. New and improved harvest practices for use on steep slopes and fragile soils are two such problems. Cable logging may offer the best approach to solving the management as well as the research problems on publicly owned land.

Planners on private land also seek to develop more efficient harvest techniques. Here, esthetic values cannot be neglected but economic values must take precedence. Here, too, the cable logging concept looms large, but a machine competitive with conventional wood products harvest systems—especially on gently sloping land—has yet to be built. The right machine must safeguard environmental values and it must fully meet the economic needs of forest land managers who derive their livelihood from wood products harvest.

Wider use of cable logging might go far toward solving problems of nonpoint pollution of forest water resources, particularly in mountainous topography. Public Law 92-500 places control of nonpoint pollution foremost in the planning of many foresters at the national, state, and local levels. But somehow, an often overlooked principle must be brought to the attention of those who deal with nonpoint pollution: Perpetually limpid water is delusory.

> Pollution can never be totally eliminated, only reduced through various means. Thus, the level of pollution is not an "either-or" choice between the spotlessly clean environment and the dirty environment, but rather a choice between various levels of pollution. [Sesco 1973]

Cable logging may be our best choice for holding nonpoint pollution of forest streams at acceptable low levels.

This review provides a representative but by no means exhaustive look at the literature on the environmental effects of cable logging. Perhaps the most useful outcome of it is assurance that cable logging can minimize some unwanted effects on the forest environment stemming from our economy's ever increasing need for wood products. But even cable systems must be operated efficiently and conscientiously if society is to realize their full potential to provide the needed amenity and economic values from the eastern forest. There is no substitute for the careful direction of skilled and dedicated people. Lacking such direction, no harvest system can provide these values. Given proper application of the cable logging concept and the skills to apply it, cable systems should be relied on increasingly for wood products harvest acceptable to all people concerned with forests and the environment. No harvest method is known that better protects environmental values.

Years ago, a Russian forester (Tkatchenko 1930) expressed a thought that is relevant to this discussion:

> The history of science abounds in striking examples of definite ideas having been expressed by early thinkers, poets, and the people in general, before finding universal recognition. . . . The so-called "new ideas" are frequently only a synthesis of old ones expressed at different times, which failed to fall on ground favorable for their propagation. . . . Our domain of forestry likewise presents instances of modern ideas whose origin ascends to remote antiquity.

Tkatchenko wrote of ideas whose time has come; in this case, cable logging in Eastern United States. Today's devices do indeed synthesize principles developed years ago, and even now are under technological refinement. The cable logging concept, its steam-powered form rendered obsolete by cutting the old-growth forest, may yet become preeminent in harvesting the second growth.

## CONCLUSIONS

Given conscientious and skilled application of the cable logging concept:

1. Soil, water, and visual resources of the eastern forest are better protected than by any other system for harvest of wood products.
2. No harvest system is less damaging to residual trees or is more beneficial to forest wildlife.
3. A cable logging system has yet to be developed that is optimally operational in the eastern forest.

## LITERATURE CITED


Aulerich, D. Edward, K. Norman Johnson, and Henry Froehlich.
1974. **Tractors or skylines: What's best for thinning young Douglas-fir?** For. Ind. 101(12): 42-45.

Barnes, C. P.
1938. **The problem: Land unfit for farming in the humid areas.** *In* Soils and men U.S. Dep. Agric., Yearb. Agric. p. 60-67.

Bates, C. G.
1924. **The erosion problem.** J. For. 22(5):498-505.

Biltonen, Frank E., William A. Hillstrom, Helmuth M. Steinhilb, and Richard M. Godman.
1976. **Mechanized thinning of northern hardwood pole stands: Methods and economics.** USDA For. Serv. Res. Pap. NC-137, 17 p.

Binkley, Virgil W.
1965. **Economics and design of a radio-controlled skyline yarding system.** USDA For. Serv. Res. Pap. PNW-25, 30 p.

Black, Peter E., and Philip M. Clark.
1958. **Timber, water, and Stamp Creek.** USDA For. Serv. Southeast. For. Exp. Stn., Asheville, N.C. 12 p.

Bond, Robert.
1959. **Radio controlled skidding introduces electronics into logging.** Northeast. Logger 8 (6):22-23, 57.

Brooks, A. B.
1910. **Forestry and wood industries.** W. Va. Geol. Surv. 5. Acme Publishing Co., Morgantown, W. Va. 481 p.

Brush, Robert O.
1976. **Spaces within the woods.** J. For. 74(11): 744-747.

Burke, Doyle.
1975. **Running skylines reduce access road needs, minimize harvest site impact.** For. Ind. 102(5):46-48.

Church, Thomas W., Jr.
1972. **The Chuball: A new device for selectively logging steep slopes.** North. Logger Timber Process. 21(2):8-9, 27-33.

Clarkson, Roy B.
1964. **Tumult on the mountains: Lumbering in West Virginia. 1770-1920.** McLain Printing Co., Parsons, W. Va. 410 p.

Cline, Charles.
1956. **Bundle skidding in Alabama's hills.** Pulpwood Prod. Sawmill Logging 4(7):6-8.

Conway, Steve.
1976. **Logging practices: Principles of timber harvesting systems.** Miller Freeman Publications, San Francisco 416 p.

Cook, Walter L.
1972. **An evaluation of the aesthetic quality of forest trees.** J. Leisure Res. 4(4):293-302.

Craul, Phillip J.
1976. **Impacts of logging in northern hardwoods: Effects on soils.** North. Logger Timber Process. 25(2):8, 34.

Deitschmann, Glenn H., and David E. Herrick.
1957. **Logging injury in Central States upland hardwoods.** J. For. 55(4):273-277.

Dickerson, B. P.
1968. **Logging disturbance on erosive sites in north Mississippi.** USDA For. Serv. Res. Note SO-72, 4 p.

Dissmeyer, George E.
1976. **Erosion and sediment from forest land uses, management practices and disturbances in the southeastern United States.** *In* Proceedings of the third Federal inter-agency sedimentation conference, Denver, p. I-140 - I-148.

Echelberger, Herbert E.
1976. **Impacts of logging in northern hardwoods: Public reactions.** North. Logger Timber Process. 25(2):9.

Fobes, E. W.
1947. **Transporting logs by skyhook.** USDA For. Serv., For. Prod. Lab. Rep. R 1637-17, Madison, Wis. 2 p.

Fobes, E. W.
1950. **Observations on Wyssen cable logging in New York and Canada.** USDA For. Serv., For. Prod. Lab. Rep. II-D30, Madison, Wis. 11 p.

Frothingham, E. H.
1931. **Timber growing and logging practice in the southern Appalachian region.** U.S. Dep. Agric. Tech. Bull. 250, 93 p.

Gainer, Carl E., and Charles E. Lohr.
1970. **Report on forest management practices on National Forest lands in West Virginia.** W. Va. For. Manage. Pract. Comm., W. Va. Legislature, Charleston, 49 p.

Garrison, George A., and Robert S. Rummell.
1951. **First-year effects of logging on ponderosa pine forest range lands of Oregon and Washington.** J. For. 49(10):708-713.

Gibson, Harry G., and Cleveland J. Biller.
1975. **A second look at cable logging in the Appalachians.** J. For. 73(10): 649-653.

Giordano, G.
1959. **Logging cable ways.** U.N. Publ. FAO/ECE/LOG/60 mimeo, 145 p.

Gove, William.
1971. **The Meadow River Lumber Company.** North. Logger Timber Process. 20(4):10-13, 26-29.

Hawley, Ralph C., and David M. Smith.
1954. **The practice of silviculture.** 6th ed. John Wiley & Sons, New York 525 p.

Heagy, James F.
1960. **Logging small watersheds in western Pennsylvania.** Proc. Soc. Am. For. Annu. Meet. 167-168.

Herman, Francis R.
1960. **A test of skyline cable logging on steep slopes—a progress report.** USDA For. Serv. Stn. Pap. 53, Ft. Collins, Colo. 17 p.

Herrick, David E., and Glenn H. Deitschman.
1956. **Effect of tractor logging upon hardwood stands.** For. Prod. J. 6(10):403-408.

Hewlett, John D., and James E. Douglass.
1968. **Blending forest uses.** USDA For. Serv. Res. Pap. SE-37, 15 p.

Kidd, W. J., and J. N. Kochenderfer.
1973. **Soil constraints on logging road construction on steep land, east and west.** J. For. 71(5):284-286.

King, W. W.
1963. **Merchantable stem skidding and damage.** J. For. 61(11):846-849.

Klock, Glen O.
1975. **Impact of five postfire salvage logging systems on soils and vegetation.** J. Soil and Water Conser. 30(2):78-81.

Knight, D. K.
1976. **Cable logging gets shot in the arm: Resurgence in South highly probable.** Loggin' Times 5(10):5-7.

Kochenderfer, James N.
1970. **Erosion control on logging roads in the Appalachians.** USDA For. Serv. Res. Pap. NE-158, 28 p.

Kochenderfer, James N.
1977. **Area in skidroads, truck roads, and landings in the central Appalachians.** J. For. 75 (8):507-508.

Kochenderfer, J. N., and G. W. Wendel.
1978. **Skyline harvesting in Appalachia.** USDA For. Serv. Res. Pap. NE-400, 9 p.

Koroleff, A., and C. R. Silversides.
1949. **Transport of wood by gravity over suspended wire.** J. For. 47(2):84-92.

Lacey, James D. and Company.
1920. **Report of reproduction study, West Virginia Paper and Pulp Company Lands; Pocahontas, Randolph, and Webster Counties, W. Va.** MS. in Archives, W. Va. Univ., Morgantown, 23 p.

Lull, Howard W.
1959. **Soil compaction on forest and range lands.** U.S. Dep. Agric. Misc. Publ. 768, 33 p.

Lull, Howard W., and K. G. Reinhart.
1965. **Logging and erosion on rough terrain in the east.** *In* Proceedings of the Federal interagency sedimentation conference. U.S. Dep. Agric., Agric. Res. Serv. Misc. Publ. 970, p. 43-47.

Lysons, Hilton H., and Roger H. Twito.
1973. **Skyline logging: An economical means of reducing the environmental impact of logging.** J. For. 71(9):580-583.

Marquis, David A.
1977. **Silviculture of eastern hardwoods.** *In* Scientific base for silviculture and management decisions in the National Forest System. U.S. Dep. Agric., For. Serv., Washington, D.C., p. 29-38.

Matson, E. C.
1956. **The Wyssen skyline system.** Proc. Soc. Am. For. Annu. Meet. 116-117.

McKinney, A. L.
1934. **Logging damage in selectively logged loblolly pine stands.** J. For. 32(1):94-96.

Megahan, W. F., and W. J. Kidd.
1972. **Effects of logging and logging roads on erosion and sediment deposition from steep terrain.** J. For. 70(3):136-141.

Meyer, Gene, John H. Ohman, and Russell Oettel.
1966. **Skidding hardwoods: Articulated rubber-tired skidders versus crawler tractors.** J. For. 64(3):191, 194-196.

Miller, Edward R.
1973. **Timber harvest, a deer's best friend.** North. Logger Timber Process. 21(12):16-17, 32-34.

Minckler, Leon S.
1975. **Sustained yield: Silviculture for small woodlands.** Am. For. 81(3):34-39.

Mitchell, Wilfred C., and G. R. Trimble, Jr.
1959. **How much land is needed for the logging transport system?** J. For. 57(1):10-12.

Northeastern Forest Experiment Station.
1975. **Municipal watershed management symposium proceedings.** USDA For. Serv. Gen. Tech. Rep. NE-13, 196 p.

Northeastern Logger.
1953. **Tractor-winch logging in Northeast.** Northeast. Logger 2(4):16, 59.

Nyland, Ralph D., and William J. Gabriel.
1972. **Injuries from tree-length skidding with rubber-tired vs. crawler tractors.** SUNY Coll. For., AFRI Res. Rep. 8, Syracuse, 11 p.

Packer, Paul E.
1967. **Forest treatment effects on water quality.** *In* International symposium forest hydrology

proceedings, Pergamon Press, Oxford, England, p. 687-699.

Parker, E. G.
1976. **Cable logging systems.** North. Logger Timber Process. 24(12):14-15, 34, 36.

Patric, J. H.
1976. **Soil erosion in the eastern forest.** J. For. 74(10):671-677.

Patric, J. H., and J. L. Gorman.
1977. **Soil disturbance caused by skyline cable logging on the Fernow Experimental Forest.** J. Soil and Water Conserv. 33(1):32-35.

Perkins, Paul C.
1969. **Effect of mechanized logging on forest management.** North. Logger Timber Process. 17(11): 22-23, 40-41.

Perkins, Robert H.
1975. **The Purdue traction-cable running skyline system.** J. For. 73(8):481-485.

Perkins, Sherman H.
1963. **Helicopter logging trials in Thomaston, Connecticut.** Northeast. Logger 11(9):14-15, 32.

Prater, J. D.
1973. **The use of modern wire rope systems in the South.** *In* Proceedings Cable Logging Conference MT-95, Va. Polytech. Inst. Coop. Ext. Serv., Blacksburg, p. 82-91.

Priegel, Earl R.
1975. **Cable logging returns to the Daniel Boone National Forest.** South. Lumberman 230(2850):11-12.

Pruett, Emerson W.
1975. **Logging roads: Their location and construction.** North. Logger Timber Process. 24 (3):10-11, 25.

Pulpwood Production and Sawmill Logging.
1973. **WESTVACO weds yarders to whole tree chippers.** Pulpwood Prod. Sawmill Logging 21 (12):10-12.

Pulpwood Production/Timber Harvesting.
1976. **Highlead cable logging: Is it coming back East?** Pulpwood Prod. Timber Harvesting 24 (10):14-16.

Reinhart, Kenneth G.
1964. **Effect of a commercial clearcutting in West Virginia on overland flow and storm runoff.** J. For. 62(3):167-171.

Reinhart, Kenneth G.
1975. **Throughout the Northeast: An overview.** *In* Municipal watershed management symposium proceedings. USDA For. Serv. Gen. Tech. Rep. NE-13, p. 79-82.

Resler, Rexford A., and Robert E. Buckman.
1973. **The Falcon program: Research and development of advanced forest transport systems.** For. Prod. J. 23(1):13-16.

Ruth, Robert H.
1967. **Silvicultural effects of skyline crane and high-lead yarding.** J. For. 65(4):251-255.

Seheult, L. R.
1955. **Cable logging in eastern Canada.** Northeast. Logger 4(1):14-15.

Sesco, Jerry A.
1973. **Economics of pollution and the impact of environmental concern on the forest products industry.** For. Prod. J. 23(5):21-24.

Shafer, Elwood L., Jr.
1967. **Forest aesthetics: A focal point in multiple-use management and research.** 14th IUFRO Congr. Pap. 7, Sect. 26, p. 47-71.

Shafer, Elwood L., Jr.
1969. **Perception of natural environments.** Environ. Behav. 1(1):71-82.

Simmons, Fred C.
1957. **The impacts of new methods and machinery on forest management.** Northeast. Logger 6(1):34-35, 54-56.

Simmons, Fred C.
1959. **Logging: Yesterday, today, and tomorrow.** South. Lumberman 199(2489):195-198.

Simmons, Fred C.
1976. **Forestry industry opportunities and problems in the northeast.** North. Logger Timber Process. 24(7):8-9, 26-27, 29.

Simmons, Fred C.
1977. **50 years of change.** North. Logger Timber Process. 25(11):3, 34.

Swanston, D. N., and C. T. Dyrness.
1973. **Stability of steep land.** J. For. 71(5): 264-269.

Taylor, Heyward T., Jr., and Boone Y. Richardson.
1963. **Field tests of a whipwood yarder on National Forests of North Carolina.** Report on file, USDA For. Serv., For. Eng. Lab., Auburn, Ala. 5 p.

Tkatchenko, M. E.
1930. **Origin and propagation of forestry ideas.** J. For. 28(5):595-617.

Trimble, George R., Jr., J. H. Patric, J. D. Gill, G. H. Moeller, and J. N. Kochenderfer.
1974. **Some options for managing forest land in the central Appalachians.** USDA For. Serv. Gen. Tech. Rep. NE-12, 42 p.

U.S. Department of Agriculture
1976. **Highlights in the history of forest conservation.** U.S. Dep. Agric., Agric. Inf. Bull. 83, 56 p.

U.S. Environmental Protection Agency.
1976. **Forest harvest, residue treatment, reforestation, and protection of water quality.** U.S. Environ. Prot. Agency EPA 910 9-76-020, 273 p.

Virginia Division of Forestry.
1955. **Ragged mountain watershed of Charlottesville, Va.: Forest practices in action.** Va. Div. For. Prog. Rep. 1, Charlotttesville, 14 p.

Vogenberger, R. A., and J. A. Curry.
1959. **Watershed protective logging.** South. Lumberman 199(2489):93-94.

Walbridge, Thomas Alexander.
1960. **The design of harvesting systems and machines for use in pulpwood stands of the Tennessee Valley as dictated by intensive forest management.** Ph.D. Diss. Univ. Mich., Ann Arbor, 277 p.

Watson, Russell.
1923. **Forest devastation in Michigan.** J. For. 21(5):425-451.

Webb, William E.
1973. **Timber and wildlife.** *In* Report of the President's advisory panel on timber and the environment. U.S. Gov. Print. Off., Washington, D.C. p. 468-489.

Weisgerber, John F.
1962. **Ground and cover conditions following Wyssen skyline and high-lead logging.** Proc. 13th Alaska Sci. Conf., abstr., p. 88-90.

Welsch, David J., and Harold J. Abplanalp.
1977. **Emergency salvage of black cherry by helicopter.** North. Logger Timber Process. 25 (11):6, 7, 48, 49.

Wendel, G. W., and J. N. Kochenderfer.
1978. **Damage to residual hardwood stands caused by cable yarding with a standing skyline.** South. J. Appl. For. 2(4):121-125.

Wendel, George W., James N. Kochenderfer, and Cleveland J. Biller.
1974. **Skyline cable logging in West Virginia.** North. Logger Timber Process. 22(12):14-15.

Westveld, Marinus.
1926. **Logging damage to advance spruce and fir reproduction.** J. For. 24(5):579-582.

Wilhite, Robert G., and William R. Sise.
1974. **Measurement of reaction to forest practices.** J. For. 72(9):567-571.

Wing, Leonard W.
1951. **Practice of wildlife conservation.** John Wiley & Sons, New York, 412 p.

Wooldridge, David D.
1960. **Watershed disturbance from tractor and skyline crane logging.** J. For. 58(5):369-372.

U.S. GOVERNMENT PRINTING OFFICE. 1979—603-111/61

55

Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories and research units are maintained at:

- Amherst, Massachusetts, in cooperation with the University of Massachusetts.
- Beltsville, Maryland.
- Berea, Kentucky, in cooperation with Berea College.
- Burlington, Vermont, in cooperation with the University of Vermont.
- Delaware, Ohio.
- Durham, New Hampshire, in cooperation with the University of New Hampshire.
- Hamden, Connecticut, in cooperation with Yale University.
- Kingston, Pennsylvania.
- Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
- Orono, Maine, in cooperation with the University of Maine, Orono.
- Parsons, West Virginia.
- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- University Park, Pennsylvania, in cooperation with the Pennsylvania State University.
- Warren, Pennsylvania.